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THIS MONTH'S COVER.—Planned agriculture in a free country. This aerial view of soil conservation in the United States illustrates how the layout of a countryside can be co-ordinated to meet the requirements of conservation policy. The picture is particularly interesting in the light of the recent U.N. Conference on the Conservation of Natural Resources. *Photo courtesy of U.S.I.S.*

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Editorial Comment

Conservation of natural resources

THE United Nations Scientific Conference on the Conservation and Utilisation of Natural Resources, which was held from August 17 to September 6 at Lake Success and of which an account of the opening meetings is contained on another page, is an event of more than ordinary importance.

It covers a vast range of subjects, including as it does mineral, water and forest resources, in addition to the topic which has of late years come to bulk so prominently in the public eye, the conservation of the soil.

As the holding of the conference implies, the whole range is intimately interconnected, and the fact that it has been held is an indication of recognition that, in a world of which the populations are increasing at an ever-quickening rate, it is imperative that all the natural resources upon which mankind depends for his survival should be conserved with the greatest care and not recklessly squandered, and that the effective attainment of this end demands planning and control by Governments on an adequately correlated international basis and on a scale never previously contemplated.

It is in fact the direct negation of the long-accepted principle of *laisser faire* and the doctrine that development can be safely left to the initiative and enterprise of rugged individualism.

In a world torn by the struggle of rival political ideologies, the importance of such a gathering and the topics which it deals with are apt to be overshadowed by passing events. In the daily press, still handicapped by an exiguous supply of paper, or in the broadcast news summaries and commentaries equally handicapped by limitations of time, the claims of such a topic are heavily outweighed by the conflicting views of Premier Stalin and Marshal Tito on the particular brand of Communism which shall prevail in South-Eastern Europe, or by the vexed question whether a railway engine-driver who lives at Grantham shall be allowed to return to the bosom of his family on a Saturday night or forced to repose unsolaced and uncherished in London. On a somewhat higher plane attention is concentrated upon the perplexities of evolving a system whereby the products of one region can be freely exchanged with those of another, unhampered by the outmoded currency and exchange restrictions which mankind has imposed upon himself. The urgency of this problem cannot, of course, be gainsaid, but it must be viewed in the perspective of the reflection that if natural resources are not conserved the materials which form the basis of the exchange will steadily dwindle.

It is to be hoped therefore that the deliberations of the conference will be productive of considered observations accompanied by carefully-marshalled data, which can at least help to provide a basis for concerted future policy, and perhaps lead to a solution of the problem upon which the whole future of mankind depends.

Rubber perplexities

THE plantation rubber industry is probably the outstanding example of one which from its infancy has relied upon scientific assistance and advice for its development. Had it not been for this, it is certain that it could never have made the astonishing progress it achieved between the commencement of this century and the outbreak of war with Japan in 1941, when the annual value of its produce (negligible in 1900) exceeded £100,000,000. At every stage of its development it has relied upon the scientist to solve its problems and this trust has been well repaid, since all the numerous difficulties, inseparable from establishing as a crop a naturally occurring forest tree never previously cultivated, have in turn been satisfactorily surmounted.

The scientific organisation of the industry is indeed a model which could well be copied by others, comprising well-staffed and well-equipped research organisations in the countries of production coupled to, and linked with, parallel organisations in Britain and some continental countries and with provision for consultation and collaboration between the three principal producing countries on an international basis.

The latest and most serious threat the industry has ever experienced comes from the synthetic substitutes, which under the stress of war have assumed such prominence, and in which manufacture in the U.S.A. has made such amazing strides.

Since the war further technical developments have occurred and, using as their basis petroleum products, the synthetic industry is producing materials which fill with increasing efficiency the requirements of manufacturers at an ever-lowering cost. A great advantage they possess is that, as they are prepared from compounds of known purity, it is possible to meet manufacturers' special requirements with considerable exactitude, more exactly, in fact, than the plantation product can do, since this is almost certainly itself not a simple compound, but a mixture of isomers in proportions which may vary with the conditions under which

the tree is growing. It is known, for example, that rubber from different localities may show quite appreciable variations in rate of cure, plasticity and other factors, while similar variations also occur in the rubber produced from different clones.

Prior to the war research in the plantation industry was largely concentrated upon increasing yields, thereby cheapening production costs ; but since the war, and with the ever-increasing competition from synthetics, attention has been turned more and more to questions of quality, since upon quality the ability of natural rubber to compete with its synthetic rivals must in the last resort depend.

The first stage is, of course, to eliminate, so far as practicable, differences occasioned by variations in methods of extraction and processing with the object of producing as uniform a product as is possible. This, coupled with efficient inspection and grading before shipment, should accomplish the desired end. The next step appears to be to establish how far quality is influenced by climatic and soil conditions or by inherent variations in the character of the planting material and to use this knowledge in grading rubber for consumption. The third stage arising from the previous one is to ascertain how far quality can be influenced by treating the soil in which the tree is growing or the tree itself. Much still remains to be known regarding the manner in which rubber latex is produced in the tree and the physiological and chemical processes by which it is effected, while its exact function is still to an extent obscure, although it is known that it is probably connected with nutrition of the plant and is not, as was at one time thought, a provision of the plant for repairing wound damage. Greater knowledge in this regard is certainly an essential preliminary to successful influence on the quality of the rubber produced.

Research on the physiology of the tree has been in progress for some time past and it is now announced that a conference is to be held in Malaya during September which will be attended by representatives of scientific and planting interests for the purpose of discussing questions of quality and future work on the subject. Such a meeting appears to be particularly appropriate at this juncture.

History contains several instances of agricultural industries of which the products have been superseded by synthetic materials produced by the chemist ; the vegetable dye industries are cases in point. None of these industries was, however, equipped either scientifically or financially to meet this competition. With rubber it is different, since its whole development and tradition is bound up with research, while, thanks to this and to sound business policy, it achieved its present position. It is indeed a question of whether the skill and ability of the plant breeder, the plant physiologist, the biochemist and the rubber technologist, applied to harnessing living plants to the needs of man, can produce results parallel to those which the organic chemist and the technologist can achieve when dealing with a raw material which, though now ordinarily regarded as of mineral origin, is really a product of biological activity in a bygone age.

Marxist agriculture

EVENTS behind the Iron Curtain always have a particular interest for those outside it and this applies equally to agricultural matters as to social and political conditions. In these circumstances the account of the Stalin plan for Russian agriculture which appears in a recent number of the Commonwealth Agricultural Bureaux's publication, *Soils and Fertilisers*, is worthy of attention, since it affords more than a glimpse of the lines upon which developments are being essayed.

Basically, the problems confronting Russian agriculturists are identical with those of other similarly situated parts of the world, notably the great plains of the U.S.A. and Canada. Fortunately or unfortunately, nature is not susceptible to influence by propaganda or ideological concepts, and the proof of the pudding must be in the eating, no matter whether it is cooked in a basin rigidly fashioned in accordance with the concepts of the Marxist-Leninist ideology or is of a pattern which conforms to the less formalised traditions of the West.

The plan itself is of the most grandiose character; it is designed to occupy a period of 15 years; it applies to the European part of the semi-arid regions of the U.S.S.R. with an annual rainfall of 10 to 20 in. and embraces 80,000 collective farms and about 120,000,000 hectares of land (300,000,000 acres). It commenced in the current year and is to be operated on all state and collective farms within the area.

The principles underlying it are apparently the adoption of a grass-grain rotation, presumably in replacement of the older grain-fallow system, combined with ' correct ' cultivation methods and systems of manuring, the use of selected seed, the development of irrigation and the extensive establishment of protective forest belts. It is the application on a vast scale of the principles enunciated by the late Prof. V. R. Williams, which apparently are accepted as infallibly correct in the Soviet Union. One of the principles apparently is that the main limiting factor to agricultural productivity is the farmer rather than the soil he works, and that there are not good and bad soils but only good and bad agriculture, a statement which outside the U.S.S.R. hardly seems likely to meet with unreserved acceptance.

There is, of course, nothing particularly novel about the various separate items of the system or

in the manner in which they have been integrated into the system as a whole. There do, however, appear to be some doubts as to how far they represent the results of systematic experiment and how far they are empiric. The central principle is, of course, the grass-grain rotation, which is in accordance with the march of ideas in many parts of the world, while the central problem is the maintenance of fertility and the prevention of erosion, particularly wind erosion, which is a characteristic danger of steppe and prairie cultivation, no matter whether it is in the U.S.S.R. or the Great Plains of the U.S.A. and Canada.

It is in the method of dealing with the problem that the chief contrast lies; experience the world over has shown that to guard against these perils the exercise of a greater degree of control over the operations of the farmer by the state than was formerly regarded as practicable or desirable is needed. It is impossible to achieve this if the matter is left to the unfettered action of the individual especially when farming is practised on a multiplicity of small-holdings.

In the U.S.S.R. the solution that has been attempted is the elimination of the small-holder and the collectivisation of the whole agricultural pattern under the supreme direction of the state. It demands unquestioning belief in the wisdom and judgment of those responsible for the evolution and operation of the system and unquestioning obedience to its decrees by those who have to carry them out no matter how unreasonable they may appear. It thus automatically discounts individual initiative, a factor which has been productive of most of the advances which agriculture has achieved in the past.

By contrast the U.S.A. and most of the Commonwealth countries, when faced with similar problems, have adopted the methods best exemplified in the soil conservation legislation of the U.S.A., which enables soil conservation districts to be established by popular consent in which a large measure of control can be exercised over land use by individual farmers through the agency of democratically appointed Soil Conservation Boards.

Leaving on one side the somewhat extravagant claims and prophecies of what the Russian system is going to accomplish (and which it may be remarked are a necessary part of the system itself), it should be possible in due course and as the Russian plan unfolds, to gauge to some extent the respective merits of these two very different approaches to an identical problem.

British Association meets

COINCIDING as it did with the holding of the United Nations Conference and with so eminent an authority in the sphere of scientific agriculture as Sir John Russell in the presidential chair, the 1949 meeting of the British Association for the Advancement of Science was of more than ordinary interest.

In his presidential address, excerpts from which we publish on another page, Sir John covered in outline the whole field of agricultural endeavour and epitomised his own interpretation of the signs and portents which influence the agricultural outlook for the world. As is well known, Sir John is not one of the more pessimistically-inclined prophets who foresee, or claim to do so, the impending doom of the human race, owing to accelerating population growth and the inability of production to keep pace with it; rather does he point to the truly amazing accomplishments which the application of science to agriculture has brought about during the past 50 years and pins his faith to the ability of science to provide solutions for the formidable array of problems which confront us, provided, and always provided, means can be found for translating the results of research into practice and applying them on a sufficient scale, and for preventing the dissipation of fertility by improvident and wasteful methods.

To us it seems that the correctness of the premise is indisputable, but the factor which is imponderable is that of time; can mankind in the preoccupation with other seemingly more immediate issues so adjust his production methods as to provide the necessary safeguards within the time available to avert disaster ? The answer lies with the future, but the time is short.

The session on food and people which took place on Saturday, September 3, at the City Hall, Newcastle, provided a forum for the discussion of the range of topics which this question involves and we hope to include a report of this in a subsequent issue of this journal.

Nitrogen and grass production

IN the sixteenth and seventeenth centuries English farming made great progress by learning from the Dutch. To quote from Tickner's *Social and Industrial History of England*, ' the yield from the land was raised to something like two and a half times what it had formerly been. The association with Holland was a valuable one in this respect. The Dutch were noted dairy farmers, with methods well worth copying. . . .' The spirit of this comment is no less true today, especially if the use of nitrogen for grass production is considered. No country has used so much nitrogen per acre and so consistently as Holland ; even in the days between World Wars I and II when illusory food surpluses depressed world agriculture, the Dutch farmers applied two cwt. of sulphate of ammonia per acre to their grassland as an *average* figure, and the best farmers often applied as much as six cwt. As a result the Dutch acre of pasture supported

twice as many head of cattle as the British acre, and the Dutch cow produced about 60% more milk per lactation. We have made the comparison between Dutch and British grass production but similar or even sharper differences could have been shown by taking almost any other country in the world.

The enormous influence of nitrogen upon grass yields has also been proved by research. Post-war tests in Scotland by the Hannah Dairy Research Institution have demonstrated that even dressings as high as 18 cwt. of ' nitro-chalk ' per year need not be regarded as too excessive to be economic. Yield increases of more than 60% were given but the effects upon protein content were far more striking. So increased was the protein content of the grass that, although the actual crop weight rose by 60% to 70%, the actual output of total protein rose by more than 200%. There is no other association of a nutrient and a crop that leads to such remarkable increases in nutritional quality as this association of nitrogen and grass.

Nor should these Scottish results be looked upon as exceptional. Similar results have emerged from numerous tests in the United States, notably at the Massachusetts Experiment Station, during the past twenty years. Nitrogen produces not only more grass but much better grass. It may be true that this generalisation applies only to soils which are granted a reasonable annual rainfall.

In most of Australia, nitrogenous fertilisers have so far been ineffective and the nitrogen supply problem is solved by establishing clover crops. But wherever grass grows fairly easily as a result of a sufficient and reliable rainfall, far more nitrogen should be used per acre. In Britain the Committee on Industrial Productivity recently pointed out that only a quarter of her 18,000,000 acres of grassland received any nitrogenous fertiliser at all, and an immediate expansion of the nitrogen fertiliser industry was urgently recommended.

It should not be supposed that the application of nitrogen as a single and isolated operation will lead to high grass yields year after year. But of all operations in grassland farming, the operation giving the largest responses to quite small variations, is the application of nitrogen.

D.D.T.—a story of errors

THE story of D.D.T. is an excellent example of how *not* to publicise a new agricultural material or method. As one of the first technical secrets of the war to be released, it was swamped with an inflated number of headlines and radio talks from the first announcement of its birth. No commercial organisation could have given D.D.T. the publicity that Anglo-American officialdom gave it towards the close of the war ; the insect world was conquered unconditionally in printer's ink and in the short waves and the long. Any child beginning a promising career in such a fashion is bound to cease being a prodigy and become a suspected delinquent instead.

Let us first list the metaphorical flies in the D.D.T. ointment. First was the fear that it would kill the bees and stop pollination, but this has been the eternal question asked about all new insecticides. D.D.T. survived this traditional difficulty fairly well; its toxicity to bees, if care was taken in times of spraying, was no greater than that of other established orchard sprays. Far more serious was the assistance D.D.T. gave to the red spider by killing off those insects which had formerly kept red spider populations down. This was a major disability that had to emerge with practice ; and it cannot be denied today that new insecticides are being developed to deal with the increased attacks of red spider which have resulted from the use of D.D.T.

Simultaneously came the scare about D.D.T. accumulations in milk and meat, and there is no doubt that when cattle feed upon D.D.T.-treated fodder the fat-soluble D.D.T. in spray residues builds up in the fats of the animals. Milk can contain enough D.D.T. to be toxic to flies, and the concentration of D.D.T. in a product such as butter can become dangerously high from the point of view of feeding to children.

Next it was found that house-flies could develop resistance to D.D.T. Flies which managed to resist its effects stayed alive to breed so that by a counteraction of the natural selection type, an increasing number of flies with inherited resistance was found in areas where D.D.T. had been heavily used. There is evidence that this has, indeed, been taking place in the United States since 1947. The question agriculturists must ask is whether other insect pests can in time do the same.

The most recent blow, however, is the charge in America that the mysterious disease attributed to ' virus X ' is actually no more and no less than D.D.T. poisoning. Medical authorities have accused D.D.T. manufacturers of marketing D.D.T. products for general use without first ' compiling full information about their toxicity.'

We do not believe ourselves that D.D.T. is a burst bubble. Too much was expected of it far too quickly, and now each instance of trouble or failure recoils upon D.D.T. with added force. Had D.D.T. been developed slowly and quietly these difficulties would have occurred on a smaller scale and they would, in any case, have been looked upon in their proper light, as the normal growing pains of any new product or idea. Such growing pains are either overcome or, if not, are faced as reasonable limitations of the product. Fools rush in where angels fear to tread, and in the case of D.D.T. publicists certainly did enormous harm by rushing in where scientists and expert agriculturists would have been content to tread slowly and cautiously.

Better Crops Through Hybrid Seed

MALE STERILITY BECOMES USEFUL

THERESA ASHTON, M.A.

Commonwealth Bureau of Plant Breeding and Genetics, School of Agriculture, Cambridge

Hybrid maize being cultivated at an experimental station in the U.S.

Hybrid vigour is a comparatively new factor in crop improvement; it manifests itself by increased productivity in plants raised from first generation hybrid seed. Its practical application has been developed most extensively in the U.S.A. in relation to the maize crop and its extension to other crops is now proceeding.

In this article the author discusses and reviews the subject.

THE superior vigour sometimes shown by the hybrid progeny produced by crossing two unrelated varieties or in-bred strains of a crop, is a highly useful tool of the plant breeder. Hybrid maize is the outstanding example of how this curious bonus of nature, still not wholly explained by the geneticists, can be utilised. In maize, inbreeding and controlled hybridisation has brought about spectacular increases in yield in the United States, resulting in crops 25% higher on the average than those obtained by using seed of the 'open-pollinated' varieties. By sowing hybrid maize seed annual harvests exceeding those produced 20 or 30 years ago by over 700,000,000 bushels are now being produced on 10 million fewer acres.

Hybrid maize

Maize is normally cross-pollinated; when inbreeding is forced upon it by the breeder greatly reduced vigour results. On the other hand, when suitable inbred plants are crossed, they produce highly vigorous progeny, giving higher yields and showing much greater uniformity than open-pollinated maize from which the inbred strains were originally derived. The secret of the phenomenal success of hybrid maize depends both on hybrid vigour and in the use of selected inbred plants for the parent stock.

The outstanding success of hybrid maize has naturally stimulated research in the exploitation of hybrid vigour in other crops, particularly in the United States. In a few cases first-generation hybrid varieties have actually been developed for commercial use, while in several others research has reached such an advanced stage that the production of hybrid seed is well within sight.

Hybrid vigour has always been an elusive advantage, since its expression is ephemeral, reaching its maximum only in the first hybrid generation. This restriction presents a difficult problem to the breeder and for commercial purposes the cross must be repeated for each new seed supply.

The characters of the maize plant make it particularly well-suited to controlled hybridisation on a mass scale. Most of the hybrid maize seed in the corn belt of the U.S.A. is obtained by crossing two single hybrids, each the result of hybridising two inbred strains. Fortunately, maize bears male and female flowers separately on the same plant, and in seed production the inbred strains or single crosses are interplanted in rows, the field being isolated to prevent contamination by pollen from outside sources. Before the male inflorescences or tassels of the plants to be used as female parents begin to shed their pollen, they are removed, but the plants acting as the male parents are left with their tassels intact. In this way 100% cross-pollination between chosen parents is effected, through natural wind-pollination. Thus hybrid maize seed can be easily produced, and the increased cost of hybrid seed in comparison with ordinary open-pollinated seed, due to the extra labour

involved in the production, is far outweighed by the economic benefits. Few other crops are, however, so well equipped as maize to aid the plant breeder in his exploitation of hybrid vigour.

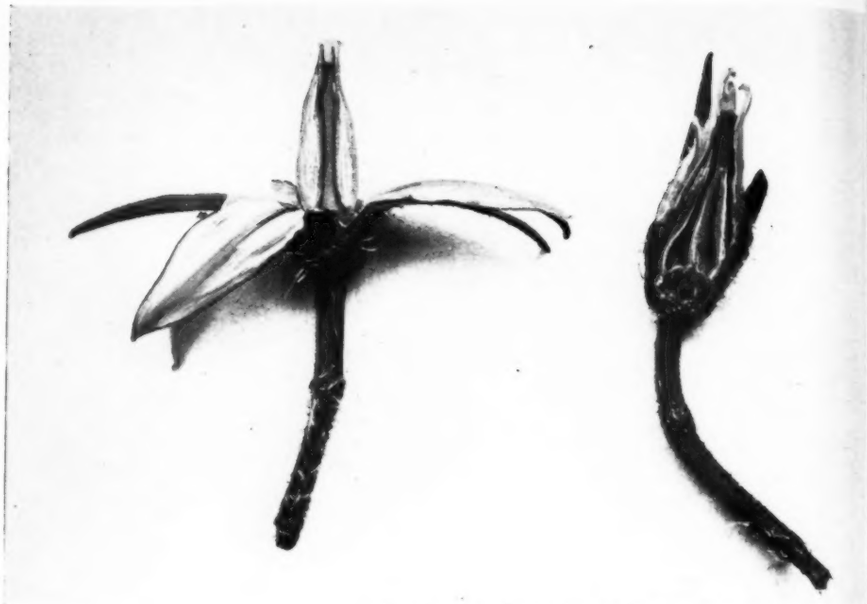
Male sterility aids onion breeders

The use of abnormal male sterile forms as female parents is a valuable method of eliminating the need for hand emasculation, and notably with onions, male sterile lines which produce no pollen themselves but set seed readily when pollinated from normal male fertile plants are being utilised with outstanding success, as a result of the pioneer investigations of H. A. Jones and his colleagues in the United States.

Onion seed is normally produced through cross-pollination, the pollen being carried from one flower head to another by insects, but since each small flower is perfect, containing both male and female parts, self-pollination within a single head may occur. For controlled crossing, emasculation of the flowers is therefore necessary in ordinary circumstances. It has long been known that inbreeding in the onion reduces vigour as in maize, resulting in loss in bulb weight, but that inbred lines could possess advantages such as resistance to bolting, improved keeping quality and uniformity in bulb characteristics. Experimental crosses between two male-fertile inbred lines by hand emasculation and pollination had shown increased vigour and bulb weight, but it was the fortunate discovery of a male sterile form in the variety Italian Red that made possible the commercial production of hybrid seed. In 1944 the first hybrid variety, California Hybrid Red No. 1, was released for commercial growing, as the result of crossing the male sterile form, Italian Red 13-35, with Lord Howe Island.

The use of Italian Red 13-35 as a parent is limited, however, on account of its poor keeping quality, late maturity and lack of wide adaptability. Transference of the male sterility of this line to other more suitable types was therefore undertaken by the American plant breeders; it was made possible by precise knowledge of the mode of inheritance of this useful character.

The inheritance of the male sterile condition depends upon the interaction between a recessive gene in the nucleus and a non-nuclear or cytoplasmic factor, the latter being inherited only through the maternal parent. It is believed that two types of cytoplasm exist; all plants with one type, symbolised as *N*, produce viable pollen; plants possessing the other type (*S*) are male sterile. A recessive gene for male sterility (*ms*) influences pollen production when carried by plants with the *S* type of cytoplasm, but in plants with *N* type of cytoplasm it has no effect. The male sterile line Italian Red 13-53 is therefore of the genetic constitution *S ms ms*, one *ms* gene having been contributed by the male and the other by the female parent. Plants with *N* cytoplasm are invariably male fertile, and may be of the constitution *N Ms Ms*, *N Ms ms* and *N ms ms*. Plants of the constitution *S Ms Ms* and *S Ms ms* are also male fertile, although their cytoplasm is of the type *S*, because they carry the dominant gene *Ms*.



(Photo reproduced from technical bulletin 274 U.S. Dept. of Agriculture

Normal and functionally male sterile flowers of tomatoes of the John Baer variety. In the sterile form the petals do not spread out in the normal way

Using Italian Red 13-53 as the source, male sterility has now been successfully incorporated in important commercial onion varieties in the United States. Fortunately, male fertile types of the constitution *N ms ms* have been found in most of the varieties so far tested and, by crossing Italian Red 13-53 (*S ms ms*) with a male fertile variety of the constitution *N ms ms*, offspring of the male sterile type *S ms ms* are produced. Gradually, by back-crossing, *i.e.* repeating this form of cross, male sterile lines can be produced practically identical with the commercially desirable type repeatedly used as the male parent, *e.g.* Sweet Spanish or Crystal Wax.

Once developed, the male sterile line has to be maintained, for the continuous back-crossing between the male sterile line and the normal male fertile inbred line is necessary; at the same time the male fertile inbred is automatically maintained, since this interpollinates itself normally. The aerial bulbils formed by some onion varieties are also useful for propagating male sterile lines and male fertile inbreds, and applications of growth hormones may here prove useful in increasing the number of bulbils produced. Finally, crosses between male sterile lines and selected inbreds must be tested to determine the combinations which produce the best first generation hybrids from the commercial standpoint. It should perhaps be pointed out that whether a commercial hybrid is male fertile or male sterile is immaterial and inbred lines of any constitution may be used as the male parent.

Yields up to 50% higher than those of ordinary onions have been secured and it is expected that before long the new hybrid varieties will be released for growing on a large scale. Hybrid production has greatly enlarged the scope of onion improvement, for inbred lines can be developed with all kinds of improved characters, in particular, increased resistance to disease and pests, and at the present time intensive work is being carried out by the United States Department of Agriculture in co-operation with the State Agricultural Experiment Stations to produce superior inbred lines for raising hybrid seed. In the case of one disease, downy mildew, the renowned Italian Red 13-53 has again proved valuable, since it provides a source of resistance to this disease.

Hybrid sugar beet on the way

In the case of sugar beet also, which is cross-pollinated chiefly by the natural agency of the wind, the use of male sterility in controlled hybridisation between inbred lines is giving very promising results in

the United States, although the breeding work has not yet advanced so far as with the onion. Male sterility in the sugar beet is also the result of combined cytoplasmic and genic inheritance, and increased sugar production and improvements in other characters can be obtained by sowing the hybrid seed of crosses between selected inbred lines. As in onions, improvements can be incorporated in the inbred lines, such as resistance to curly top virus or to leaf spot due to the fungus *Cercospora*, reduced tendency to bolt and desirable root shape. A very valuable feature of hybrid sugar beets is their uniformity, a point of major importance in the mechanisation of harvesting operations.

Hybrid seed in sorghum possible

The crossing of varieties of self-pollinated crops, which are practically equivalent to inbred lines of cross-pollinated species, also results in marked hybrid vigour when appropriate parents are used. Among field crops, first-generation hybrid seed may have a useful future in sorghum, as work in the United States has shown. Finding the most suitable combination of varieties entails special difficulties, since some hybrids mature too late or grow too tall for convenient mechanical harvesting of the grain crop. The rank growth they produce in some cases also has disadvantages, causing overloading of the silage cutter, making the bundles of stover (dried stalks and leaves) too heavy and unwieldy, severely exhausting the soil moisture and nutrients, and forming a heavy stubble difficult to plough in and which decomposes slowly. It has, however, been found that in some cases increased grain and forage yields may be secured without too great a gain in height and with sufficiently early maturity.

Various techniques have been considered to circumvent the need for emasculating the tiny flowers in each head. On an experimental scale, hot-water treatment of the head has been successfully used to effect bulk emasculation without damaging the female organs, but attempts to emasculate flowers with herbicides and other chemicals have failed. The abnormal character of male sterility probably offers the most likely method of solving the problem. J. C. Stephens has discovered a male sterile form in the variety known as Blackhull kafir, in which the flower is normal in every other respect. Male sterility, however, can only eliminate emasculation and the problem of pollination remains. Possibly under certain conditions fertilisation by natural wind pollination might be sufficient, using closely-paired rows of the two parents as an alternative. Some form of portable air blast apparatus has been ingeniously suggested.

Higher yields of tomato

Hybrids between suitable commercial varieties of the tomato, another self-pollinated species, can give 20 to 50% higher yields than ordinary varieties, and besides greater uniformity in fruit characters they usually have the great advantage of yielding earlier, the greater production being due to the increased number of fruits produced. Little commercial use, however, has so far been made of hybridisation, since the labour involved in hand emasculation and pollination makes the hybrid seed too expensive ; only about 1 oz. of such seed can be produced by one man per day. With the use of male sterile forms, the production of hybrid seed per man employed can, however, be increased by six to eight times. Male sterility of various types is fairly frequent in the tomato. One of the most useful types is the functionally male sterile variety, John Baer, discovered in the United States. In this the flower is complete but the petals are tightly compressed about the stamens and pistil and do not spread out as in a normal flower. The anthers contain good functional pollen, but the wall of the anthers is so tough that it fails to rupture and release the pollen. This curious but highly useful character is inherited by means of a single recessive gene, and is being transferred to other varieties by back-crossing.

This form can be easily reproduced in the large numbers required for commercial hybrid seed production, since the pollen can be collected from the anthers by artificial rupturing and used to self-pollinate the functionally sterile flowers.

(*Courtesy of U.S.I.S.*)

An agronomist of the U.S. Department of Agriculture applying pollen from a parent corn plant to the silks of another corn plant selected as the parent of a hybrid, being developed in one of the Department's experimental stations

Mechanical pollinator

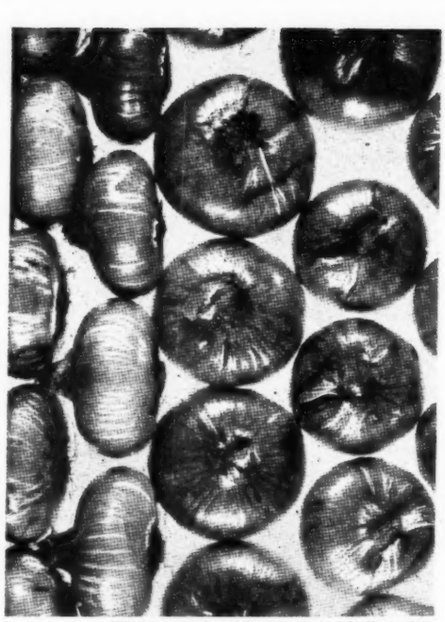
Improvements in the collection and application of pollen are also likely to facilitate the production of hybrid tomato seed. For instance, a mechanical pollinator devised by Cottrell-Dormer in Queensland makes possible mass pollen collection and application. This little apparatus, easily portable and worked by electric batteries, consists essentially of a fine wire loop, which is made to vibrate within a glass pollen collecting chamber. By placing the staminal cone of the flower in the loop and causing the latter to vibrate, the pollen is rapidly shaken from the anthers into the chamber. In pollinating, the protruding stigma is brought into contact with the pollen in the chamber. When pollination is done out of doors, the pollinator has the advantage of not being affected by the wind.

Among other horticultural crops hybrid vigour has been experimentally shown to have potentialities in the musk-melon, water-melon, cucumber, squash or pumpkin (*Cucurbita maxima*), marrow (*Cucurbita Pepo*) and the egg-plant or aubergine, and its commercial use is again mainly a ques-

tion of devising suitable crossing techniques. At the John Innes Horticultural Institution the crossing of inbred lines of raspberries, including male sterile forms, is also being studied; not only might it lead to improved yields but it might also help to solve the problem of virus disease in plants propagated from canes.

Hybrid lucerne and insect pollination

In most of the crops considered so far, male sterility is the basis of the techniques employed for cross-pollination, but in the case of certain crops, however, the breeder relies simply upon a high degree of natural pollination. In the case of lucerne, which is cross-pollinated by insects, work is being done in the United States and Canada on the production of hybrids between cross-fertile and relatively self-sterile clonal lines and on double cross hybrids between single crosses. Such single cross and double cross hybrid seed, obtained by natural cross-pollination by insects, contains a proportion of selfed seed, but experimental yield tests have shown that as much as 25% selfed seed planted along with pure hybrid seed reduced the yield of the mixture very little below that of the pure hybrid seed, doubtless because the more vigorous hybrid plants crowd out the weaker ones from the selfed seed. Experimental single cross hybrids have given 20 to 27% higher forage yields than the standard variety Grimm. Since lucerne is a perennial crop, a given parent can be maintained indefinitely and the use of pure breeding inbred lines is not essential, while several seed crops can be obtained from one planting, so long as the stand remains satisfactory.



(Photo reproduced from technical bulletin 874 U.S. Dept. of Agriculture

Onions of the Yellow Danvers Flat variety, inbred 5 generations. Note uniformity of size and shape resulting from inbreeding

Sunflower hybrids in Canada

The war-time shortage of vegetable oils stimulated interest in sunflower cultivation in several countries, including Canada, where in 1943 the crop was grown on a commercial scale for the first time. At an early stage Unrau and his colleagues at the Dominion Forage Crops Laboratory, Saskatoon, explored the possibilities of hybrid sunflower seed, and in 1945 a first-generation hybrid was released under the apt name of Advance, the product of natural crossing between an inbred line of Mennonite and the variety Sunrise.

The large handsome head of the sunflower is mainly cross-pollinated by insects, but self-fertilisation among the bisexual florets of the disc can also occur. When two parents are interplanted to produce hybrid seed the extent of natural cross-pollination may be as high as 95.8%, but it is considered that 60% crossing is adequate to give high yielding seed, since the more vigorous hybrids crowd out the plants from selfed seed as in lucerne, and this crowding-out effect can be enhanced by increasing the seeding rate.

Conclusion

Exploitation of hybrid vigour is certainly one of the more important methods available to the plant breeder for improving crop varieties. Its uses are, however, limited by the character of the crops themselves and it is only when these are favourable that it can be widely applied. It is, for example, unlikely that, except possibly in the case of a few crops, hybrid seed will oust the use of ordinary seed to the extent that has been the case in the corn belt of the U.S.A.

Expansion of Rhodesian Cotton Industry

THIS year the Southern Rhodesian cotton crop has broken all records. The stockyards at the Government spinning mills at Gatooma are piled with bales of raw cotton and, although the season ends soon, supplies are still arriving (it is reported in a special story in the *Rhodesia Herald*). To keep pace with the increasing supply a second mill of similar design and capacity is being built near the original mill and should be in operation towards the end of 1950. The new plant will comprise 17,500 ring-spinning spindles and 850 doubling spindles. Native labour in Rhodesia has proved adaptable to cotton farming, and the Mondoro Reserve is becoming one of the richest cotton-producing areas in the colony. In 1947 the natives produced approximately 75,500 lb. from their smallholdings. Last year the figure had risen to 259,100 lb., and this year the cotton mills have produced more than 1,000,000 lb. of raw cotton for £34,429 from native growers. Generally, the natives' yield per acre is far in advance of the Europeans', and the quality of cotton produced is also superior. The average acre yield in the native areas is almost 800 lb., yet many European farmers are satisfied if their lands produce half this quantity. The comparative quantities of cotton seed issued to natives in the last three years indicate the rapid growth of this type of farming. Three years ago natives received 10,295 lb. of seed, the following year 27,404 lb., and last year 87,405 lb. Experts at the Gatooma Mill estimate that the issue will exceed 170,000 lb. for the next planting season.

New picking machine

A new cotton-picking machine which recently arrived in Bulawayo should prove a boon to the Europeans. Before the machine can be used the entire crop must be dusted with aero cyanamid dust, which causes the leaves to fall and the cotton boll is then ready for automatic plucking. The quality of Rhodesian cotton is partly due to the Research Branch of the Cotton Breeding Station at Gatooma. After 25 years' research they have bred a hardy strain of cotton well suited to Rhodesian conditions. It resists many of the insect pests and has to be quick maturing owing to the short rainfall period.

The manager of the textile mills near Gatooma, who uses only the yarn spun at the Government mills, declares that, in more than 20 years' experience overseas, he has never seen cotton of better quality than the Rhodesian product.

Crop damage in Majorca

Reports from Madrid indicate that there have been heavy rains in Aragon and Catalonia and some damage to standing crops has been caused in Majorca.

Pastures and Forage Crops in the Tropics

R. O. WHYTE Ph.D., B.Sc.

Director of the Commonwealth Bureau of Pastures and Field Crops

Of recent years great advances have been made in pasture management and the cultivation of forage crops in temperate countries, and the range of materials and of methods which can be employed is well understood. Under tropical conditions the matter is equally important, but many of the controlling factors differ considerably from those in temperate regions, and methods have to be evolved which suit the altered conditions. Progress at present lags behind what has been achieved in temperate climates, although knowledge is growing.

IT is necessary to adopt a restricted meaning of the term 'pasture' as applied to tropical conditions if this discussion is to have any shape within its allotted scope. The word 'pasture' has become too widely used for conditions very different from those of Western Europe where it originated. The Oxford Dictionary defines it as herbage for cattle, or 'a piece of land covered with this.' It is doubtful if a European would accept a 6-ft. high stand of elephant grass as a pasture, although it does provide herbage for cattle.

For the purpose of this article, its scope will be restricted to those areas of land on which herbage plants are cultivated for grazing, soiling or other use, or to those areas which may be termed grazing grounds and which approximate to the European idea of a pasture. We will therefore discuss intensive 'pasture' management, and disregard for the moment those extensive areas of grassland, savannah, desert scrub and other associations which provide sustenance for livestock, and which require to be managed according to ecological principles.

The best fodder crops for the tropics appear at the moment to be the tall, erect perennial grasses to which pasture management on the British pattern cannot be applied. The average yield of green forage from cultivated tropical grasses under good conditions should be double or treble that which is usually obtained from a good grass ley in England. The nutritive value of tropical herbage at its best is distinctly lower than that of young English pasture herbage, but the total yield of digestible nutrients per acre must be considerably higher due to the longer growing season.

Grazing versus soiling

Pasturing represents the cheapest method of providing animal fodder, obviating as it does the carting of fodder to the stall and of manure from the stall. Under certain economic and climatic conditions in the tropics, however, the cutting and carting of green herbage daily for feeding to stock at the steading is preferred. Both methods have their respective uses. Soiling is especially applicable where land is short or where grade dairy cattle are the main class of livestock, as these require protection against the hot tropical sun. The grazing technique is generally preferable for the rearing and development of healthy stud animals and young stock and for the economical production of beef cattle.

Only some few of the tropical grasses, such as *Panicum maximum*, *Brachiaria mutica*, or *Melinis minutiflora*, can stand anything approaching heavy grazing without damage, and this depends again upon the grazing habits of different classes of livestock. It would appear to be desirable to work out some combination of grazing and soiling for particular conditions, governed by the type of livestock, the nature of the herbage, seasonal availability

Fenced paddocks for rotational grazing at the Government Stock Farm, Serdang, Malaya. The pasture is under carpet grass (Axonopus compressus), showing also farm buildings and shade trees

of fodder and so on. Systems of grazing with appropriate rest periods will also have to be evolved.

Shade on pasture

The inclusion of shade trees on pastures may serve a number of purposes. They may merely provide shade for the livestock in the heat of the day; they may, if members of the Leguminosae, help to provide a better protein balance for the livestock, if browsing and pollarding are permitted or the foliage might be fed on the soiling system.

Recent observations in Malaya have indicated an even more important function. Grass growing under the shade of rain trees (*Enterolobium saman*), with their wide-spreading not-too-dense canopies, is of stronger growth and better quality than grass growing in situations exposed to the sun. Medium shade provides ideal conditions for growth of carpet grass (*Axonopus compressus*). When conditions are sufficiently favourable, this vigorous stoloniferous grass is able to suppress or supersede coarser grasses, including even *Imperata cylindrica* if cut and grazed. It may therefore be an advantage to plant grazing grounds with fairly widely spaced suitable shade trees, preferably leguminous.

There are also preliminary data to indicate that the protein content of *Axonopus compressus* is higher under leguminous trees (14.32%) than under other trees or oil palms (10.92%) or in the open (9.68%).

The white clover of tropical pastures may therefore be a tree.

Grass species

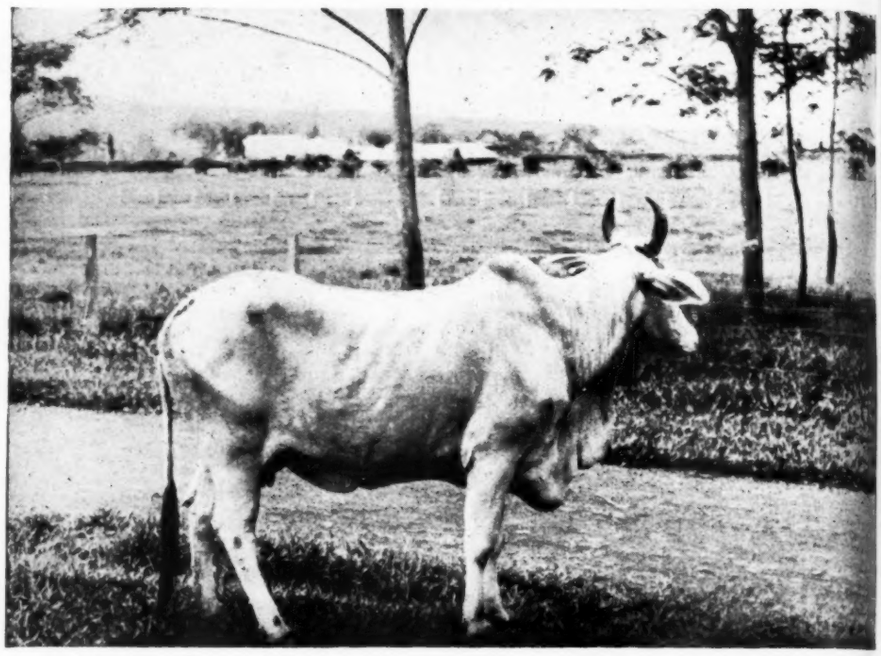
The classification of tropical pasture grasses proposed by D. D. Paterson provides a useful basis :

(*a*) *Pasture or turf-forming species*, comprising the more important bottom grasses capable of forming a more or less dense, close, turf sward:

- Savannah or carpet grass (*Axonopus compressus*).
- Bahama or devil or doob grass (*Cynodon dactylon*).
- Pimento or buffalo grass (*Stenotaphrum secundatum*).
- Centipede grass (*Eremochloa ophiuroides*).
- Java grass (*Polytrias praemorsa*).

(*b*) *Trailing species*, which do not form any turf but produce a thick tangled cover 1 to 3 ft. in depth, composed of a profusion of inter-twined leafy runners:

- Para or Mauritius grass (*Brachiaria mutica*).
- Molasses or Wynne grass (*Melinis minutiflora*).
- Seymour or Barbados sour grass (*Andropogon pertusus* = *Amphilophis sp.* ?).
- Star grass (*Cynodon plectostachyum*).



Indian cow on carpet grass paddock

(*c*) *Tufted or stool-forming species*, mainly tall, erect cane-like grasses:

- Elephant grass (*Pennisetum purpureum*).
- Guatemala grass (*Tripsacum laxum*).
- Guinea grass (*Panicum maximum*).
- Uba or other thin sugar-cane (*Saccharum sinense*).

These lists do not include at least two of the important grasses of East Africa, Rhodes grass (*Chloris gayana*) and kikuyu (*Pennisetum clandestinum*), and new grasses are constantly appearing in the literature as an indication of reserves in the natural floras as yet untapped. From West Africa one heard reference some time ago to *Andropogon gayanus* and *Pennisetum pedicellatum*.

Not many of the tropical grasses have yet been the subject even of mass selection for the production of improved strains. Kenya has its Nzoia Rhodes grass, Uganda and Hawaii strains of elephant grass resistant to *Helminthosporium*, but this branch of research is in its infancy. One feels that it may yet be preferable to test more genera and species rather than to embark on expensive breeding programmes.

There is also the problem that many of the tropical grasses produce little or no seed and have to be reproduced vegetatively. As labour costs increase, this will become a decided disadvantage and a study of causes of this deficiency will be desirable.

Leguminous species

The tropics are outside the range of tolerance of lucerne and the true pasture clovers, and the search for a leguminous species which will form a stable association with the tropical grasses is one of the most difficult in tropical pasture research. Legumes are desirable in order to improve the protein content of the herbage, and to provide nitrogen in the soil for the benefit of associated grasses and other species. None of the species so far tried appear to have the necessary climatic adaptation, or the necessary growth form to permit them to withstand grazing and cutting or to thrive in competition with tall grass species. In Trinidad, for example, legumes from other tropical countries, including species of *Alysicarpus*, *Lespedeza*, *Stylosanthes* and *Pueraria*, have been tried, but only *Stylosanthes*—the so-called Townsville lucerne—shows any promise.

In Trinidad also it has been possible to obtain a fair cover of the following more or less perennial legumes: *Centrosemapube scens*, *Calopogonium muconoides*, *Dolichos hosei*, *Indigofera endecaphylla* and *Pueraria javanica*. All require some six to twelve months to develop a satisfactory mat and afterwards require very careful management and periodic hand weeding to prevent them from being smothered and killed by the dominant weeds of the locality. The species of *Indigofera* has been reported to be the most promising, particularly under the conditions obtaining in the island of Puerto Rico.

For these reasons it may be necessary to adopt methods of incorporating legumes in the pastures which are quite different from those common in temperate lands.

Young cattle grazing on paddocks under carpet grass showing the type of sward

The inclusion of leguminous trees and shrubs as shade trees, hedges or windbreaks has been suggested; the tropical floras appear to be rich in such plants, for example species of *Erythrina*, *Gliricidia*, *Leucaena*, *Albizzia* and *Prosopis*.

There are, of course, many annual or short-term leguminous forage and cover crops which may be grown on cultivated land in the tropics, such as *Mucuna aterrima*, *Dolichos lablab*, *Vigna unguiculata*, *Phaseolus mungo* and *Cajanus cajan*. These are, however, relatively expensive to grow, limited and variable in their yields of green fodder, and have to compete for land space with a food crop which may be of greater immediate value to the cultivator. Further, if they are grown for their grain, they cannot be regarded as ideal soil-improving crops in a crop rotation.

The problem of the pasture legume is therefore of primary importance under humid tropical conditions, first to discover whether it is really desirable and feasible to emulate humid temperate pastures in this respect and, if so, to test all available species for adaptation to the climatic and biotic environment concerned.

Conservation of fodder

Although the growing season of humid tropical pastures may be said to be generally longer than that in humid temperate countries, there are nevertheless, periods when the productivity of pasture species may be low and conserved fodder in the form of hay or silage is required. Under most humid tropical conditions, the flush of growth which might be conserved occurs during the wet season when the making of hay would be difficult if not impossible. There are a number of reports of successful silage-making under tropical conditions, and there appears to be no reason why further research on this method of conservation should not show that it is generally applicable. Problems may arise because of the lower initial protein content of the herbage to be ensiled, and possibly also because of variations in keeping quality under tropical conditions.

A number of enquiries have been received at the Bureau of Pastures and Field Crops concerning the value of artificial drying in tropical conditions. Officers have, for example, been concerned at the great loss of potential fodder which is produced by the flush of seasonal growth in tropical grasslands, but which cannot be harvested or grazed. It has been suggested that a portable drier burning wood fuel might be the answer. It must, however, be pointed out that the artificial drying of grass is economic in humid temperate lands such as Great Britain when the legume or grass is cut at an early stage of growth and a high protein content can be obtained. It would appear theoretically to be difficult so to time the movement and operation of a portable drier in tropical grass areas that the herbage was always cut at an appropriate growth stage. The generally low protein content of tropical herbage is another factor to be considered.

It is therefore suggested that, although grass-drying may be possible under certain conditions in the tropics, research might with greater advantage be devoted to the conservation of flushes of growth in the form of silage, in order that methods can be evolved for the use of agricultural instructors and advisers.

Chemical composition and nutritive value

Animals in the tropics may have to eat very large amounts of fodder in order to obtain their nutrient requirements. When elephant grass in Trinidad was compared with pasturage in England on a monthly cropping rotation, even the least mature cuts of elephant grass gave a very low protein percentage. The more rapid growth of the tropical fodder appears to produce a much quicker drop in the protein percentage, so as to make it impossible to obtain from elephant grass a fodder with a close nutrition ratio. In an insular tropical climate as obtains in the West Indies, the rainfall incidence is the seasonal factor which has most influence on plant growth. A definite correlation exists between monthly precipitation and composition of herbage. The dry matter, crude protein and ash percentage all vary inversely with the rainfall. In the wet months there is a fall in the percentage of these three constituents. On the other hand, the crude fibre percentage tends to increase during the wet season. As the productivity of elephant grass is at its highest in the heavy rainfall months, this seasonal fluctuation in composition of the grass means that when the crop is growing most vigorously the nutritive value per unit weight of herbage is at its lowest.

Any evaluation of the tropical grass species must obviously be based on total yield, under an appropriate grazing or cutting system, and seasonal chemical compositions of the herbage. Under Trinidad conditions, for example, elephant grass has proved a failure due to its susceptibility to disease, and Guatemala grass (*Tripsacum laxum*) has demonstrated its superiority as a silage crop. Elephant grass is, however, one of the most popular tropical fodders, and the new strains resistant to *Helminthosporium* being developed in Hawaii and elsewhere may be of great economic value.

Work on the mineral content of tropical grasses is also desirable, as there are indications that some species such as *Melinis minutiflora* are lower than others in mineral content, although they may appear to be promising from other aspects.

Alternate husbandry

Interest is at present widespread in the various types of resting breaks which may be incorporated into farming systems to give the soil a rest from a period of con-

tinuous arable cropping and to acquire renewed fertility in terms of soil structure or other character. In a broad sense and as applied to tropical conditions, alternate husbandry can be regarded as covering everything from a grazed bush or grass fallow in shifting cultivation to a true crop rotation partly composed of a pure or mixed herbage stand for grazing, or for feeding in a stall or yard with complete transfer of the manure to the land.

Striking evidence of the effects of a temporary ley on soil structure and resistance to erosion has been obtained by Dr. W. S. Martin and his collaborators while working in Uganda. Soil which had been cropped continuously for seven years received greater benefit (expressed in yield of a subsequent cotton crop) after a period under a cover of *Pennisetum purpureum* than after the legume, *Centrosema pubescens*. If the period of arable cultivation has not been too long, natural regeneration of a complete cover of the grass may be achieved in six months. Under Ceylon conditions, a three-year period of grass fallow under the same grass is suggested, even though this means that an appreciable part of a holding will not be producing economic crops during this period.

Some of the main factors concerned in the development of the temporary resting or grazing ley in the Colonial Empire are (*a*) the degree to which the cultivators are willing or can economically afford to take the long-term view and sacrifice immediate return from cash crops for a method of maintaining fertility, (*b*) the capacity for natural regeneration of a suitable resting herbage, or the availability for planting or sowing of suitable species, which do not have characters undesirable when the ground is next to be ploughed, (*c*) the availability, when grazing or animal feeding is to be adopted to obtain an economic return from the resting period, of suitable animals to utilise the fodder provided, and of a market for the animal products, and (*d*) the absence of controlling factors such as tsetse fly, religious customs, cereal diets, and so on.

The main characteristics required of a grass for temporary leys under tropical conditions are: (*a*) ability to form a complete cover rapidly, (*b*) at least moderate persistence under heavy grazing if need be, (*c*) ease of eradication of tufts or root systems when it becomes necessary to revert to arable cropping, and (*d*) availability of planting material in the form of a commercial seed supply. Under Kenya conditions, for example, Rhodes grass is suitable for the purpose, whereas kikuyu grass (*Pennisetum clandestinum*) has the undesirable features of being strictly limited by its climatic requirements and of possessing a system of strong rhizomes, making eradication difficult. It is furthermore difficult to obtain seed from many of the potentially valuable tropical grasses.

Fodder supply and animal husbandry

In conclusion it is desirable to stress that improvements in source and type of animal fodder have to be made alongside parallel improvements in the capacity of the livestock to utilise that fodder and to provide a maximum economic return on the higher costs involved. If developments in these two directions are properly balanced and integrated, it will be found that they can play an important part in a system of land use on a sustained yield basis, dependent upon optimal conservation of soil and water, and the maintenance of fertility.

Smaller European Demand for U.S. Seed

AN increase in European supplies of most field and vegetable seeds, and a shortage of dollars in certain countries have curtailed the demand for United States' seed in Europe, according to a report prepared for the Office of Foreign Agricultural Relations, U.S. Department of Agriculture, by George C. Edler, agricultural statistician of the Bureau of Agricultural Economics.

Mr. Edler's report is based upon a first-hand study of field and vegetable seed production and demand in Europe conducted in 1948 under the Research and Marketing Act. Countries covered by the study were Austria, Belgium, Czechoslovakia, Denmark, England, France, Germany, Hungary, Italy, the Netherlands, Sweden and Switzerland.

The report says that the European Recovery Programme has stimulated European purchases of United States' seed, and will probably continue to do so, but that certain countries are spending scarce dollars on other United States' exports they feel are more urgently needed.

Mr. Edler states, however, that the quantity of seed exported to Europe could be greatly increased. He reports that European farmers have little knowledge of the merits of United States' seed, and that more informational effort to promote better understanding of its quality should prove profitable.

European countries have provided a market for significant quantities of field and vegetable seeds produced in the United States, and seed shipments from this country during and immediately after the war contributed heavily to European food production. Europe also has been an important source of certain United States' seed imports.

Copies of Mr. Edler's report, 'Field and Vegetable Seed Production and Demand in Europe,' are obtainable from the Office of Foreign Agricultural Relations, U.S. Department of Agriculture, Washington 25, D.C.

Aerial Fertiliser Application in New Zealand

IT is reported that the New Zealand Government are studying the possibility of improving the fertility of 10,000,000 acres of hill land by the application of fertilisers from aircraft. What is contemplated apparently is the top dressing of hill land with superphosphate which has been compressed into pellets. Apparently this method of handling has been found to be the most convenient and the most effective for this particular purpose.

It is also considered that under the conditions in question the large scale application of fertiliser in this way is cheaper than any other method, being given the difficulties to be encountered in traversing broken hill country if the applications were made from the ground.

It is stated that the New Zealand Government are in consultation with the Air Ministry with a view to ascertaining the most suitable form of aircraft for the purpose. Obviously what is wanted is one of the big capacity types and among others the Hastings troop carrier is being considered.

Limitations in regard to available supplies of superphosphate are probably a limiting factor to the rate at which the development can be undertaken, and at present it seems likely that the maximum which it will be possible to treat in any one year will be 750,000 acres. In these circumstances the achievement of the full programme will take 13½ years.

Phosphate deficiency is a common fault of hill pastures the world over and if the New Zealand experiment succeeds it may well provide a valuable contribution to the practical solution of the problem and, incidentally, be the means of adding appreciably to the world's meat supplies.

World Cereals Today

WHEAT

THE MAINSTAY OF THE TEMPERATE REGIONS

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Wheat is the cereal which, more than any other, dominates the economy of the world. It may be outstripped by rice in the total number of people who depend upon it for their staple food, but there can be no question of the prominent part it plays in world affairs.

It has been the subject of a vast amount of research, which has resulted in the production of many new and improved forms. No crop has received more attention in efforts to economise labour by mechanisation, and certainly no crop has been the subject of more international discussion or, in the past, has been influenced to a greater extent by speculative factors. In this article some of the more important factors which influence production of the crop are discussed.

THE origins of civilisation in the Old World are closely connected with the cultivation of wheat as a field crop. At the present time the greater part of the civilised world in temperate regions leans on wheat as the 'staff of life.' A crop which has played this important role in the life of man through so many stages of history and in such diverse parts of the earth is indeed a remarkable one. It is a cosmopolitan crop, cultivated in every continent and in all parts of those continents except where conditions are arctic or wet-tropical. Historically it has not only supported civilisations in prehistory, ancient history and mediaeval history, but continues to do so in modern times, when we accept as the natural order of things the transport of basic foodstuffs over thousands of miles.

Important cultivated forms

Wheat obviously must have a very wide range of adaptation and it is not surprising

(*Courtesy: U.S.I.S.*

The first step in developing a new wheat variety. A plant breeder transfers pollen from the head of one variety to the head of another. Each of the varieties used for this crossing was selected because of a certain characteristic—in one case, perhaps, disease resistance; in the other, high yield. The seed produced by the resulting hybrid plant will be planted in the greenhouse and the plants that spring from it will be thoroughly tested

to find that its botany is complex and by no means fully understood. In fact it is extremely doubtful whether all the species of wheat in the world are yet known, while collections of agricultural varieties on a world scale soon run into the tens of thousands. All forms of wheat are classified under the genus *Triticum*, the limits of which are not very clearly stated. The species of wheat are divided into three groups according to their chromosome numbers, diploid species being those with 14 chromosomes in their body cells, tetraploids 28 and hexaploids 42. This basis of classification is particularly useful to the plant breeder for, with few exceptions, the fertility of an interspecies hybrid is roughly indicated by the grouping of the species involved.

From the point of view of the world wheat crop, only a few of the numerous species of *Triticum* deserve mention. None of the diploids are responsible for any sigficant part of world production. Among the tetraploids, the macaroni or hard wheats (*T. durum*), with rather long, hard translucent grain, are grown around the Mediterranean and in other parts with somewhat similar climates; *T. turgidum* (familiar to English farmers in the form of Rivet) producing a short, hump-backed grain of poor baking, though often of good milling quality, is grown to some extent in more northern latitudes. Its outstanding characteristics are high yield and resilient straw; the branched-ear wheats which are often reported as giving phenomenal yields belong to this species. On poorer soils and under northern continental climatic conditions, some cultivation of spelt wheat (*T. spelta*), which has 42 chromosomes, is still to be found. This species is unusual in that the ear breaks up at threshing, leaving the grain tightly enclosed in the chaff. It remains only to mention the hexaploid club wheats (*T. compactum*), which form a minor part of wheat cultivation in the region of California, before passing on to the bread wheats proper.

When most people speak of wheat, they have in mind bread wheat (*T. vulgare*), for this 42-chromosome species is far and away the most important. It is an extremely variable species, notably in respect of shape and colour of the glumes, grain colour, ear density, awns and of such important agricultural and economic characters as spring or winter habit, earliness, length and strength of straw, baking quality and milling quality. In most forms, however, the straw is hollow immediately below the ear, while the ear is broader in face view than in profile, and the grain, though short and rather plump, lacks the pronounced hump of the *turgidums*. The classification of the enormous range of forms belonging to *T. vulgare* cannot yet be said to be satisfactory; while it is possible to arrange them reasonably well according to morphological features, the groupings thus established do not always agree with the ecological and physiological features, which in some respects are more important for agriculture. Nor need we expect that a final, perfect classification will ever be attained, for plant breeders are continually at work recombining attributes which are at present not combined in one variety.

World distribution and production

World production of wheat is based on an acreage of about 400,000,000, the total annual yield being about 6,000,000,000 bushels. So widely divergent are the conditions under which it is grown that fluctuations in acreage and yield balance out reasonably well, to within 10% more or less than the average. But this does not mean that the world trade in wheat is correspondingly stable. Even if the consumption of wheat were as constant as it might be were it not affected by economic and political factors outside the scope of this article, it is important to remember that the typical wheat importing countries produce a substantial part of their requirements. (They account for about half of the world production.) Consequently their demand for wheat imports fluctuates with their annual production. Conversely, in the typical exporting countries, the amount available for export is a surplus left after home requirements for food and seed have been met. Since the latter are *reasonably* constant, while total yields in each country vary considerably, the surplus for export fluctuates widely. These elementary considerations show that the rational ordering of the world wheat trade is a particularly knotty problem, but, what is more to our immediate purpose, they underline the importance of achieving greater stability in yields.

In attempting to assess, however roughly, the technical achievements and possibilities for improvement in the volume and stability of wheat production, it is essential to consider different geographical areas separately. The conditions vary so much in different parts of the world that quite different problems are encountered. Of the total world production, nearly one quarter is in the U.S.S.R., over a quarter in the rest of Europe; China and India together produce about a sixth and another sixth is produced in North and Central America. The contributions of South America, Oceania and North and South Africa add up to about one tenth of world production.

The two great factors causing fluctuations in yield of wheat from year to year are climatic variations (especially precipitation) and disease; of these, climate is the more decisive. Both have this important feature in common, that their effect is enhanced when conditions approaching monoculture obtain over wide areas, as is in fact the case with wheat in the great exporting countries. Canada affords a good example of this.* In the years 1944 to 1948 Canada had a total wheat acreage of 24.2 million acres, mostly in the prairie provinces, 14.1 million acres in Saskatchewan, 6.8 million acres in Alberta and 2.5 million in Manitoba. Over the greater part of this vast wheat belt, wheat is the only crop grown; one, two or three crops of wheat, according to climate and soil of the locality, are succeeded by a fallow. With a 41-year national average yield of 16.2 bushels per acre, the lowest yield was 7.0 bushels in 1937 and the highest 26.1 bushels in 1915. In Saskatchewan, the very heart of the wheat belt, the fluctuations were even wider. While epidemics of black stem rust (*Puccinia graminis tritici*) have played their part in causing these fluctuations, precipitation has been the more important factor.

Specialised methods

The mechanisation of cultivation and the development of a system of cultivations which, avoiding ploughing, controls weeds and leaves a cover of trash to reduce soil drifting, coupled with the complete mechanisation of harvesting by the use of combines, have reduced Canadian labour requirements to such an amazing extent that one man can handle about 600 acres. The other great improvement is the introduction of varieties with mature plant resistance to stem rust—undoubtedly one of the greatest achievements of plant breeding. The type of resistance involved was derived from other species of wheat and put an end to the long continuing struggle between the breeders and the fungus—the breeders won and the problem of black stem rust in the hard, red, spring wheat belt is now regarded as solved. It is estimated that the replacement of Marquis by the new rust-resistant varieties (Thatcher, Renown, Regent, Apex, Redman) has added 120 million bushels to the annual production. The encouraging feature of these improvements is that not only do they increase the productivity of labour and land, but also that they help to stabilise yields; soil drifting in dry periods and

* See Hopkins, *Emp. J. Exp. Agric.*, 1949, 17, 92-104.

Courtesy: U.S.I.S.)

Wheat of a new variety is carefully harvested by hand in the experimental field of an agricultural research station in the U.S.

stem rust both play significant parts in fluctuations in annual production and to the extent that they are controlled so the fluctuations are reduced.

Other possible methods of increasing and stabilising yields are the extension of the cultivated acreage, the greater use of fertilisers and the introduction of crop rotations. It is estimated that the area cultivated in Canada could be increased by 45 million acres, which is just over half the present acreage (89 million acres). This would obviously increase production and, since the potential additions lie mostly in more humid regions, the fluctuations due to drought would probably be reduced.

Experiments on the use of nitrogenous and phosphatic fertilisers have shown that, depending on the climate, soil zone, soil type and the fertility of the individual field, increases in yield of from 2 to 10 bushels per acre are obtained. It is calculated that the total amount of fertilisers used in 1946 was only enough to apply 25 lb. per acre to one twelfth of the wheat acreage. There is clearly great scope for increasing production by this means, though whether a corresponding effect on stability of production could be obtained is not so evident; the effect of fertilisers is least in those areas where the fluctuations are greatest, namely in the drier regions.

The same is true of the introduction of crop rotations. At experimental stations in the more humid regions, especially in the black soil zone, the introduction of hay crops into the rotation has led to substantial increases in yield, sometimes of 100%, but in the drier regions the benefits have not been nearly so striking. On the vexed question as to whether the monoculture of wheat is ruining the prairie soils, Hopkins adopts a non-committal attitude, pointing out that the fluctuations in annual production prevent any reliable estimation of a general trend in yields and also that the average yields of wheat are slightly greater than in the United States, where cropping is more diverse.

The position of the U.S.S.R.

Another set of problems are found when we turn to the U.S.S.R., which heads the list of the world's wheat-producing countries. Before the first world war, four fifths of the population of Russia gained their livelihood from an agriculture which has been characterised as combining 'the negative features of European agriculture (relative smallness of arable area) and of American agriculture (lowness of yield),' with a resulting level of grain production 'appropriate to a country importing grain instead of exporting it.'

Soviet agriculture has this much in common with that of pre-revolutionary Russia, that its main product is grain, very nearly half of which is wheat. The important difference is that an agriculture dominated by small-scale, peasant production has been replaced by large-scale, collective agriculture. Figures given by Premier Stalin in 1939 indicate the importance of this change. In 1913, of a total crop acreage of 259 million, 232 million acres were under grain crops and produced 80 million tons. In 1938 the total crop area was 338 million acres, of which 252 million acres were under grain and produced 95 million tons; in 1937, a better harvest year, grain production was 120 million tons. The increase in production was partly due to an increase in acreage and partly to an improvement in yield, but the yield per acre was still low (about 7½ cwt. per acre in 1938).

The effect of collectivisation and the concurrent thoroughgoing mechanisation of agriculture was to be seen in the increase in grain marketed from about 21 million tons to 37 million tons between 1913-38. No indication was (or, indeed, could be) given as to whether these increases in production were accompanied by greater stability in yields, though the greater diversity of cropping indicated by the disproportionate increase in acreage of industrial, vegetable and fodder crops might be taken as a sign of better farming. The central point of the target then set for Soviet agriculture was to achieve a yield of about 10 cwt. per acre 'in the next three or four years.' Since this yield had already been achieved by 35,000 out of 187,000 collective farms in 1938, the prospects seemed good for the attainment of the target. The tragedy of war, in which 7,000,000 Soviet lives were lost and large parts of the grain-producing areas were overrun and devastated, intervened. The recovery from the effect of the war, though hindered by a severe drought in 1946, now appears to be virtually complete.

In October 1948 a decree was promulgated 'on the plan of protective forest planting, adoption of crop rotation with (perennial) grasses, digging of ponds and reservoirs to ensure high and stable harvests in the steppe and forest-steppe areas

This disused aircraft hangar at Liberal, Kansas, is being used for the storage of some half-million bushels of wheat. Air ducts in the floor will air the wheat which will be piled to the hangar's rafters

of the European sector of the U.S.S.R.' This plan, which it is intended to complete in 10 to 15 years, affects over 300 million acres of the south and central black earth belt. If it is carried through successfully, and if it produces the increase and stabilisation of yields which are to be expected from the rather large-scale experiments conducted in the U.S.S.R., then there can be no doubt that it will change the whole balance of world wheat production.

General conclusions

From this very brief review of two important wheat-producing areas certain conclusions emerge. In an area of technically very efficient wheat growing such as the hard red spring wheat belt of North America, there are nevertheless immense possibilities for increasing and stabilising yields by extension of the cultivated acreage and by the introduction of improvements in agriculture, including improved varieties. Where the agriculture is much more backward, as in pre-revolutionary Russia, the first need is for a thorough reorganisation of agriculture. The first effect of this reorganisation is to increase the available surplus for market, but it also opens the way to the introduction of agricultural improvements, to extension of the cultivated acreage and even to an attempt to improve climate on a sub-continental scale.

Glancing briefly at the other important areas of wheat production in the light of these conclusions it would seem that in China and India the great need is for a reorganisation and mechanisation of agriculture. In 1936-38 China produced annually about 700 million bushels (average yield 15.65 bushels per acre) while India produced 370 million bushels (average yield 10.95 bushels per acre). For such large acreages, these yields are not unduly low and better results seem likely to follow general improvements in production rather than efforts to raise yields.

In Europe we find the other extreme : advanced and highly mechanised farming, especially in Western Europe, with average yields exceeding 40 bushels per acre in Holland, Denmark and Belgium, and only dropping slightly below 20 bushels per acre in Poland, Hungary and Yugoslavia. In Eastern Europe there seems to be prospects of increasing both volume and stability of yields and surplus for market, as peasant agriculture is replaced by large-scale agriculture and as the requirements of the land from industry are more and more fulfilled. In Western Europe, however, the standard of farming is relatively so high that the prospect seems to be one of a slow and steady advance as technique improves and as inequalities in the level of agriculture are evened out both between and within the different countries. The position in the U.S.A. is in some ways like that in Canada, in other ways like that in Europe.

During the past few hundred years the world's population has greatly increased and the wheat crop has continued to provide a basic foodstuff for a large part of it. There seems to be no technical reason why it should not continue to do so.

Loans for Installation of Grass Driers

TO encourage the development of grass and forage crop drying, the U.K. Agricultural Departments announce a scheme of loans towards capital expenses of erection of grass-drying plant. The scheme will be open to farmers, contractors and other bodies engaged in agriculture or business ancillary to agriculture.

Loans may be made up to 75% of the total capital expenses incurred in the purchase and installation of grass-drying plant, including auxiliary plant (*e.g.* cubing machine) and adaptation and erection of buildings including reasonable storage (but not generally for field and transport equipment). Applicants for loans will be required *inter alia* to satisfy the department as to the prospects of their being able to operate successfully and economically a grass-drying plant in such a manner as to ensure the production annually of a reasonable quantity of high quality feeding stuff. The scheme applies only to new plants or extensions of existing plants set up or taken over between March 1, 1949, and June 1, 1951.

Interest on loans will be at the rate of 3% per annum, and repayment will be expected normally to be made by equal half-yearly instalments of principal and interest over about six years from the date of the first advance of loan. In exceptional circumstances longer periods of repayment may be considered. Adequate security for all loans will be required.

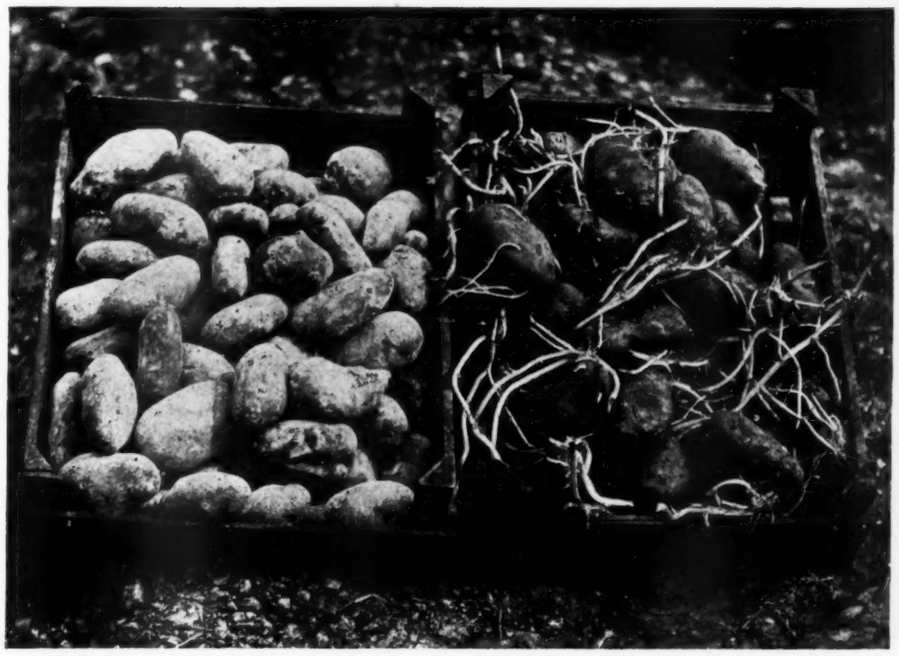
Further information about the scheme, together with copies of a leaflet Form 6/GD162 explaining the conditions, and form of application Form 7/GD162 may be obtained from the Ministry of Agriculture and Fisheries (Grassland Development Branch), No. 1 St. Andrew's Place, Regent's Park, London, N.W.1, or from the local agricultural executive committee. Farmers and other persons in Scotland should consult the Secretary, Department of Agriculture for Scotland, St. Andrew's House, Edinburgh 1.

Man-Made 'Frost' to Aid Cotton Farmers

A new ' chemical frost ' that drops the leaves from cotton plants before harvest and thus permits mechanical pickers to do a faster and cleaner job has been tested recently. The new leaf-stripping agent, ammonium thiocyanate, is said to be the first defoliant that can be applied in liquid form. Removal of leaves is important before using mechanical pickers—to prevent staining the cotton with leaf juices or contaminating it with dried, crushed leaves.

The Protection of Stored Seed Potatoes

Every year potato growers in the British Isles experience considerable losses from diseases which attack stored seed potatoes. Potato growing is extending in many parts of the world including the tropics, and development of the new short day forms may be expected to accelerate this; accordingly, problems of storage are bound to become increasingly important, and the following account of a new method of treatment is of interest.



THE chief of the diseases which attack seed potatoes in Britain are :

Dry Rot—*Fusarium caeruleum.*
Gangrene—*Phoma foveata.*
Blight—*Phytophthora infestans.*
Skin Spot—*Oospora pustulans.*
Common Scab—*Actinomyces scabies.*
Black Scurf — *Corticium* (*Rhizoctonia*) *solani.*

Commercially, the most important is dry rot (*Fusarium*) and losses of 5-70% or even 90% have been recorded. The incidence varies considerably according to the variety, the locality where grown and the degree of infection in the soil. In the case of dry rot, an additional factor which increases the severity is damage sustained during and after lifting.

Much wastage is also caused by excessive sprouting of the tubers in store. This is often severe in clamp or bag storage and may even occur in seed stored in trays.

Control measures

Early work was concentrated upon the soluble organo-mercury product ' Aretan,' in which the seed was dipped, but this was found to possess disadvantages, and it later became clear that it was necessary to use a dry method of disinfection, which fulfilled the following requirements :

1. Efficient control of disease.
2. Absence of injurious effects on the tubers.
3. Ease of application, *viz.* without machinery or interference with grower's normal routine.
4. Non-poisonous.
5. Small outlay.

After considerable research a compound was found which gave consistently good results and this has since been introduced under the registered trade mark ' Fusarex.' It is based on 2.3.5.6.tetrachlornitrobenzene.* The pure compound is colourless and odourless and is insoluble in water. It acts by slow volatilisation, and there are indications that most of the effective ingredient is dissipated after six to eight months of clamp storage. The product itself, however, stores well in bulk and does not lose strength.

*British Patent Application No. 7477/47

Tray on the left in the above photograph shows a sample of treated Majestics stored in barn on March 15, taken out of barn on May 26. Tray on right shows a sample of the same potatoes not treated

Seed treated with it is very firm and dry when taken from the pit. This is not only due to the prevention of rots and excessive sprout growth, but it appears that the compound may also influence the transpiration and respiration of the potato.

Potato production in the British Isles

In Britain the chief potato-growing districts for ' ware ' potatoes lie in Lincolnshire, Cambridgeshire, Yorkshire, Norfolk, etc., where the climate is drier than in the western and northern areas and favours a high aphid population, with resultant spread of virus diseases : on this account potatoes grown there are unsuitable for saving for ' seed ' beyond the first crop. It is therefore necessary each year to introduce vigorous virus-free stocks, mostly produced in the comparatively virus-free northern or north-western areas, chiefly Scotland, Northern Ireland and Eire, which must be transported to the English growing areas. As a result of this handling in transport, bruising of the tubers occurs, providing conditions favourable for the attack of dry rot (*Fusarium caeruleum*).

Growers take delivery during November to February, though in a few cases seed is

Treated Arran Pilots, showing 2% dry rot

graded and despatched immediately on lifting. The seed is lifted in Scotland during September and October and is normally clamped and left in the pits for one to four months ; this allows the tubers to ' sweat.' On arrival in the growing areas the seed may be stored :

1. In a clamp.
2. In trays in a ' chitting house.'
3. In bags.
4. On the barn floor covered with straw or sacks.

Experimental

The dry rot organism is present in most potato-growing areas, but to a variable extent. The varieties most susceptible to dry rot are the earlies, such as Arran Pilot, May Queen, Ninetyfold, etc., though some of the late varieties, *e.g.* Doon Star and Majestic, are also liable to severe loss.

The early, dry rot susceptible varieties are also liable to excessive sprout development during storage, and this is particularly true when the seed is kept in clamps or bags. Any treatment or modification of storage method which will obviate this wastage is bound to result in considerable saving of time and money.

The experiments were divided into two main sections, dealing respectively with disease control and sprout control.

Disease control experiments

Disease control experiments were based on the following considerations :

1. ' Dipping ' experiments demonstrated that the most effective control of dry rot was obtained by treatment within 24 hours of lifting.
2. The treatments must not interfere with the normal practice for lifting potatoes.
3. A single treatment should be effective.
4. A treatment must not adversely effect the growth of the seed.

The field method of application which has been used with most success is the so-called ' cart method.' In this the material is scattered over the potatoes as they are tipped into the cart from the ' skips ' or pickers' baskets. The dosage was 10 lb. per ton of potatoes. The cart was tipped at the clamp and the tipping distributed the material throughout the mass. The clamp was then shaped in the usual way.

The clamp of treated seed was left for a minimum of one month, after which the seed size tubers were sorted, bagged and despatched.

On receipt in England in November the tubers were emptied from the bags into storage trays and left till March the following year, when they were examined for dry rot. A second examination was made shortly before planting and the amount of diseased tubers determined as a percentage of the total tubers in the sample.

In the course of the experiments other methods of application were tried out, some of them being modifications of the cart method. One alternative which has shown promising results is to fill half the cart and then scatter 3 to 4 lb. over the potatoes. The cart is then filled and the remainder of the powder scattered on top.

It was thought possible that a fungicide blower type dusting machine would be satisfactory, but it proved unsuitable in practice owing to wind dispersal of the powder.

Collated results from 5 years' research

' Cart treatment ' at lifting, pitted, stored 4-6 weeks, despatched and boxed

	Untreated	*Treated*
Variety	% *Dry Rot*	% *Dry Rot*
Arran Pilot..	10.2	1.1
	8.2	1.3
	3.0	1.5
	12.8	2.5
	20.0	2.0
May Queen	12.1	3.3
	9.0	0.78
	25.0	5.0
	—	2.1
	—	0.9
	10.0	—
Doon Star ..	4.0	0.3
	14.7	4.0
Dunbar Rover	0.7	0.1
Duke of York	0.7	0.2

If potatoes are treated at lifting and immediately placed in trays or other form of ' open ' storage, little control of dry rot is effected. It is therefore essential to keep the seed ' enclosed ' for a minimum period of four to six weeks to be assured of the full value of the treatment.

Later treatments, *e.g.* those made about one or two months after lifting will give a partial check to dry rot, but the control is by no means complete.

Sprout control experiments

In the course of this work a repressive effect on sprout development was observed. It was recognised at once that this property is of major consequence in view of the enormous wastage from sprouting in store. Hormone products of the methyl alpha naphthalene acetic acid type have been used with success for sprout repression in ware potatoes, but suffer from the disadvantage that no control of disease is obtained, nor are they suitable for treatment of seed potatoes.

Major requirements to be observed in the control of sprouting are :

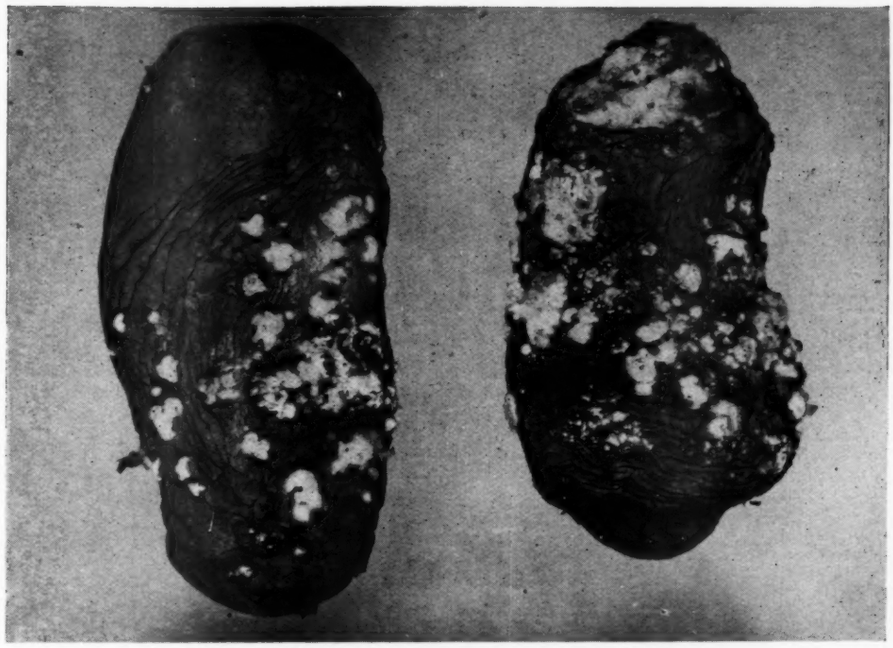
1. The latest time at which application can be made without delaying the subsequent crop.
2. The effects on different varieties.
3. The effect of differing storage conditions, temperature, humidity, etc.

In general, experiments show that the treatment will control sprouting if storage methods are suitable. A single dusting at lifting time (September - October) will generally retard sprouting if the tubers are retained in bags. However, in the case of clamp or bag storage it is essential that the seed potatoes should be aired for at least one month prior to planting. If, on the other hand, the seed is boxed on receipt, sprout development is not delayed.

Growth in the field

When seed potatoes are correctly treated and the storage conditions have been adjusted according to cropping needs, good growth in the field results. The treated seed shows superior growth and yield in comparison with untreated seed.

For example, Arran Pilot seed grown in Lincolnshire was treated at lifting time at the rate of 10 lb. per ton of potatoes and the potatoes clamped for storage as described. In November the seed-sized tubers were graded from the remainder of the crop and stored in chitting trays in a glasshouse. Planting took place in March with a batch of untreated seed for comparison, and the crop yields showed an increase in favour of the treated seed. The untreated seed yielded 9 tons 2 cwt. per acre and the treated 10 tons per acre.



Dry rot, advanced stage, showing concentric shrinkage

Toxicology

Experiments on the feeding of varying amounts of tetrachlornitrobenzene (T.C.N.B.) to rats, mice and pigs have been carried out and a summary of the results is given below :

Mice : No toxicity and no growth change was detected in a 31-day test in which mice, weighing 20 g., received 4.3 mg. T.C.N.B. daily. A dose of 35 mg. daily, however, arrested growth. Later, an average daily dose of 200 mg. per 20 g. of mouse caused death in five out of 24 mice in four days.

Rats : Oral ingestion of 6.8 mg. T.C.N.B. daily by 40 g. rats produced no inhibition of growth. Further experiments failed to show impairment of growth with a daily dose of 4 mg., but growth was arrested when 20 mg. was given daily.

Pigs : Feeding tests with pigs for a duration of six months have shown no significant difference in growth rates between the treated groups and the control animals.

It has been calculated that if treated potatoes are eaten, unwashed, by man, at the rate of 3 lb. per day, 0.182 g. of the pure substance would be consumed daily. On the basis of the mouse experiments (weight for weight), a daily consumption of 15 g. could be assumed to be harmless, while 122 g. would arrest growth.

Inhalation experiments in rats, involving exposure three times daily for half an hour to air saturated with T.C.N.B. and blown at the animals by an air pump, showed no harmful effects. The experiment was planned to assess the risks to which workers engaged in dusting potatoes in the field might be exposed.

Rabbits : Eye instillation in rabbits was followed by no reaction, but some T.C.N.B. which accidentally s'ttled in the conjunctival sac of one of the workers produced severe congestion lasting for a few days, but was followed by no ill effects.

Dermatitis has been produced artificially in the (highly sensitive) rabbits' skin. This only occurred when relatively large quantities of the substance were used, and the most recent test has failed to show clear evidence of toxicity from absorption.

The findings summarised above indicate that the product is of such a low order of toxicity that it can be regarded as non-poisonous, and that treated potatoes can safely be used for human consumption or stock feeding.

Treated Doon Star potatoes in Scotland

New Appointment

Dr. T. Eden has been appointed to organise and direct a new Tea Research Institute for East Africa with headquarters at Kericho, Kenya. Dr. Eden was for 20 years agricultural chemist at the Tea Research Institute, Ceylon. Prior to that he was attached to Rothamsted Experimental Station.

The Tea Research Institute of Ceylon showing experimental tea garden and laboratories

Recent Advances In Tea Research

T. EDEN, D.Sc., A.R.I.C.

Director Designate of the East African Tea Research Institute

1—Cultural Practices

Next year will mark the conclusion of half a century of specialised research on the cultivation and manufacture of tea in one of the first 'commodity' research stations to be founded, viz., the Indian Tea Association's Experimental Station at Tocklai, Assam. Since then similar research institutes have been set up in the East Indies and Ceylon, and a new one is in course of establishment in East Africa. These stations are responsible not only for research, but for advisory work on commercial estates on a very considerable scale, and one result of their dual activity is that probably in no other agricultural industry is research more generally and more quickly integrated into practice than in tea. This is the first of a series of articles giving an account of important advances achieved recently and dealing in turn with cultural practices, pathology and manufacturing processes.

NO matter how careful and enlightened are the agricultural methods employed in tea cultivation the results will not be satisfactory if the quality of the plant material used is poor. Unfortunately, the traditional methods of propagating tea by seed has produced a heterogeneous population of types, many of which have a very low performance. Tea is remarkably self-sterile and random cross-fertilisation in commercial seed gardens has led to the most complicated permutations and combinations of hereditable characters. A typical illustration of the great variability in performance comes from a survey of 11,000 bushes at the Ceylon Tea Research Institute. The results are set out in Table 1.

A quarter of the bushes are contributing 42% of the total yield ; 10% of the bushes are maintaining twice the average yield and four times that of the 10% at the other end of the scale ; the best 5% have a performance more than five times as high as the worst 5%. These figures clearly show that a remarkable improvement in yield should be possible if planting material could be restricted to the best types only, notwithstanding the fact that some of the disparity shown may be due to accidental circumstances.

The improvement of tea types by breeding is a slow process, in view of the number of years that must elapse before a tea seed can grow into a tea seed-bearer. Fundamental work of this kind is being carried out on a long term basis in Assam. In addition, all the Research Stations are concentrating attention on selection of good types which can be rapidly multiplied by vegetative propagation.

In India the clones of uniform material thus raised have reached the stage of commercial usefulness. A great deal of effort has been put into perfecting a propagation method that is easy, cheap and capable of being extended into commercial use. Details in technique differ from place to place according to climatic and soil conditions, but in general it has been found possible to achieve a 75 to 80% success in rooting without having recourse to special rooting media, or growth hormones. Simple shading with bamboo frames or fern, and very adequate drainage are essential. More failures are attributable to over-watering than to desiccation because of over-anxiety to keep the incipient cuttings moist. The use of a single node cutting is a uniform practice in India and Ceylon. The photograph on p. 69 shows a well developed cutting nine months old. It also shows the angle to the perpendicular at which the internode

should be inserted in order to secure the best results.

A number of qualities have to be considered in the work of selection and propagation. The most important is ease of rooting, for strains differ widely in this characteristic. Branching habit, with its concomitant density of shoot production at the plucking surface, are important determinants of yield. Resistance to disease needs a high priority now that blister blight is widespread. Finally, on the quality side, the leaf's ability to ferment normally is of the utmost importance. A few non-fermenting bushes in a field are of no consequence ; their juices will ferment readily when mixed with normal leaf at the stage of rolling operations. But a field of non-fermenting types constitutes a problem, and such fields have been known in Nyasaland. It seems likely, particularly in view of the risk of spreading disease by movement of seed and plant material from one country to another that, in East Africa particularly, there will be wide scope for the commercial development of vegetatively propagated tea.

Erosion and cultivation

Tea is grown successfully in regions having a rainfall between 50 and 250 inches per annum, and throughout the range very heavy rainstorms are a common feature of the weather. Soil erosion is, therefore a very serious problem, especially in tea grown on mountain slopes such as are met with in Darjeeling and, to an even greater extent, in Ceylon. Careless opening of land and improvident methods of cultivation can, in a decade, cause a loss of top soil and stored fertility that has only been built up by centuries of forest or savannah grasslands. Realisation of the great importance of soil conservation has led to the general adoption of drainage systems designed to impound the run off of excessive rain until the finer soil fractions have had a chance of settling out (photo right). These practical measures have thrown into prominence the problems of cultivation and weed cover, which have accordingly received considerable attention both in India and Ceylon. In both places similar conclusions have been drawn from the carefully controlled field experiments. They are, that cultivation is only beneficial insofar as it suppresses weeds and contributes to manurial efficiency and root growth. If performed too often or too vigorously it does root damage and causes loss of crop. Table 2 shows the magnitude of the losses in crop caused by excessive

TABLE 1

CONTRIBUTIONS TO YIELD MADE BY THE 'BEST' AND 'WORST' FRACTIONS OF A POPULATION OF INDIVIDUALLY RECORDED BUSHES (ADAPTED FROM TUBBS' DATA)

Size of Fraction %	*Percentage Contribution to Total Yield*		*Yield Ratio*
	Best Fraction	*Worst Fraction*	*Best/Worst*
5	11	2	5.5
10	20	5	4.0
25	42	13	3.2

TABLE 2

A—CROP LOSSES (EXPRESSED AS PER CENT. OF MEAN) DUE TO EXCESSIVE CULTIVATION (3 TIMES VERSUS ONCE ANNUALLY)

	1st Year	*2nd Year*	*3rd Year*	*4th Year*	*Whole Cycle*
Cycle 1 1936-39	0	6.0	5.9	—	5.3
Cycle 2 1939-43	3.6	1.8	3.2	4.6	3.4
Cycle 3 1943-47	2.4	4.2	4.7	2.4	3.2

B—CROP LOSSES (EXPRESSED AS PER CENT. OF MEAN) DUE TO WEED GROWTH

Cycle 1 1936-39	5	10	7.5	—	8.6
Cycle 2 1939-43	7.3	7.5	1.5	4.3	1.5
Cycle 3 1943-47	16.5	14.8	9.5	1.2	8.6

TABLE 3

RESPONSE TO FERTILISER IN PRESENCE AND ABSENCE OF WEEDS

Manurial Application	*Pounds per Acre Yield*	
	Without Weeds	*With Weeds*
N_{80} P_{60} K_{40}	880	873
N_{40} P_{30} K_{20}	770	754
Difference	110	119

TABLE 4

NUTRIENTS IN LB. PER ACRE REMOVED IN 3½ MONTHS BY 450 LB. (DRY MATTER) OF WEEDS

Nutrient	*Lb. per Acre Removed*
Nitrogen	11
Phosphoric acid	5
Potash	21

Tea planted on rough contours 46ft. x 2ft. showing soil conservation drains

cultivation (Section A) and by the prevalence of weeds (Section B) for three successive pruning cycles (i.e. the period between successive pruning operations).

On the short view, clean weeding appears to pay, but the extra crop is secured only at the expense of a very high cost for the weeding operation. It is evident from the progressive diminution in loss as the pruning cycle proceeds, that a good spread of tea, casting a heavy shade and competing with the weeds for light and root space, is a most potent means of suppressing them.

Table 3 shows that provided weeds are controlled, but are not removed from the site on which they grow, there is, under the conditions of the Ceylon experiments, little danger of their interfering with manurial response. Table 4, on the other hand, shows how much potential fertility is lost when weeds containing large quantities of nutrient are permanently removed from tea land.

To translate these results into practical terms is no easy matter. They do, however, show how vicious the circle of weeds, excessive scraping and cultivation, poor tea, less cover, followed by more weeds, etc., can become. In the interests of soil conservation excessive cultivation must be stopped and weeds must be regarded less as a cause of poor growth of tea than as a result of it.

Nutritional needs

The use of fertilisers is a long established practice in India, Ceylon and the East Indies. The efforts of the Tea Research Stations have been largely directed towards rationalising their use. It is common experience that nitrogen gives the most spectacular responses, that phosphate generally comes next and that potash, except in special circumstances, gives less noticeable crop increases except in young, recently planted tea. The reason for this exception is obscure, but results both in India and Ceylon confirm it. The time of application is also important, and this is most clearly shown on tea which has long pruning cycles (2-5 years as in Ceylon and Southern India) in comparison with the yearly pruning practised in Assam.

The general conclusions are that the best results are obtained during the middle period of the cycle. For some time after pruning, the bush has not a sufficient volume of active foliage and roots to make the most efficient use of the nutrients supplied. Towards the end of a cycle, the time between application and the check due to pruning is insufficient to allow of the full exploitation of the reserves in the plant and the soil. The point is best illustrated from the responses to the application of nitrogen, which element is subject to the severest losses. Table 5 shows the responses in dry tea secured, on a Ceylon experiment, for each pound of nitrogen applied. It is possible to present the results in this simple way because for applications up to at least 80 lb. of nitrogen per acre, the responses are strictly proportional to the dose and the law of diminishing returns does not operate. The tea crop is a young and actively growing vegetative portion of the plant at the time of the periodical harvests, which may occur as frequently as once a week. Consequently, growth response is directly translated into terms of yield.

TABLE 5

POUNDS OF DRY TEA PRODUCED PER POUND OF NITROGEN APPLIED

Cycle	*Years*	*1st Year*	*2nd Year*	*3rd Year*
1	1930-33	0.6	3.7	4.0
2	1934-37	0.9	4.4	4.8
3	1937-40	1.2	2.9	3.8
4	1940-43	2.2	6.2	6.4
5	1943-46	0.8	3.3	6.0
Mean		1.1	4.1	5.0

The maximum response of 6.4 in this experiment conforms very nearly to the maximum given in parallel work in India.

Pruning in relation to food reserves

Every approach to the nutrition of the tea plant emphasises the importance of maintaining a healthy frame and a considerable cover of mature leaf, whose function is to manufacture the elaborated food-stuffs on which depends the growth of the terminal ' bud and two leaves ' that ideally represents the plucked crop. The idea that manuring in any form forces crop at the expense of frame and permanent leaf cover, has been shown to be completely fallacious.

Dwindling frame and foliage is due to forms of mismanagement other than injudicious manuring, in most instances. Of these, over-vigorous plucking and over-severe pruning are the most frequent. The type of pruning that can be carried out successfully depends upon a number of conditions, chief of which are elevation, climate and the incidence of the Blister Blight disease, of which more will be said in a later article. In Assam, where the general rule is annual pruning, the standard of pruning is light. In Ceylon and the East Indies, tea at higher elevations, where growth is slower, runs for longer periods; sometimes four or five years elapse between pruning operations. The slower the growth and the longer the pruning cycle, the harder the pruning standard that can be safely employed. In Ceylon, whilst reasonably hard pruning in the hills above 3,000 ft. was, until the advent of blister blight, usual and fraught with no general harm, the position at lower elevations was quite otherwise. Bushes pruned so as to leave no foliage on the frame frequently showed, at the best, severe die-back of

Tea planted on sloping land which has been cleared, contoured and bench terraced

Vegetative propagation : nine month plant from simple node cutting

branches after pruning ; and at the worst, complete death. Because the roots of such bushes were systematically found to harbour a root fungus, *Botryodiplodia theobromae*, it was originally thought that this was the cause of death. But further investigation showed that Diplodia was merely an invader of the already defunct tissues, and that the real cause was deficiency of starch which is normally found stored in quantity in the tap and thick lateral roots. In Ceylon, there is a definite relationship between the elevation at which the tea grows and the average hydrolysable carbohydrate in roots of equivalent size. Tubbs' data shows that the increase amounts to 2% for each 1,000 ft. decrease in elevation and that at 6,000 ft. the carbohydrate content is roughly double that at sea level. At the higher elevations, the balance between photosynthesis of elaborated food-stuffs needed for continued growth, and losses from respiration, are favourable to the accumulation of reserves. At higher temperatures, associated with lower elevations, the bush lives a hand-to-mouth life over the greater part of its pruning cycle. Deprived of leaves by pruning, and then thrown back entirely on mobilisable reserves, it consistently happens that these are either entirely absent or too small to support the rhythm of new growth. If so, the bush either dies or recovers only slowly and on relatively few branches. The practice of lighter pruning so as to leave on the bush a few hundred foliage leaves, or of leaving for a few months a fringe of unpruned shoots at the bush's periphery, allows the plant to support itself in photosynthetically elaborated food material at a critical time, and has largely eliminated trouble of this sort. There is a tentative evidence that this type of deficiency can exist at higher elevations when bushes are so ruthlessly pruned that the buds on old wood are too dormant to respond. When this happens, the resulting foliage is insufficient to maintain the existing tissues and a similar die-back commences. It needs only a few cycles of such butchery, which in addition promotes wood-rot, to reduce a good field of tea to the appearance of devastating poverty. It is of interest that similar die-back and starch deficiency has been observed at even higher elevations in East Africa.

For Further Reading

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Water-Stabilised Earth Roads

THE construction of earth roads on farms and plantations which will stand up to traffic and, at the same time, do not involve the heavy costs associated with road-making by the usual methods, has long engaged attention.

Tar oils give a reasonably satisfactory performance when used for the purpose, but are somewhat costly. In the U.S.A. and elsewhere mixtures of 10% of Portland cement with the top soil have been of late years employed with fairly satisfactory results.

Water stabilisation probably offers the greatest prospects of success. It is well known that when the moisture content is at the right level most soils will stand up to heavy loads without becoming muddy or crumbly, and the aim of water stabilisation is to fix the water content at an amount which gives the maximum load carrying capacity. The cement process referred to above is one way of doing this.

Addition of organic materials

Recent work has shown that if, in addition to cement, certain organic materials are incorporated with the soil, satisfactory stability can be secured with considerable economies in the amount of cement needed.

The A.S.P. Company, in conjunction with the Road Research Laboratory of the D.S.I.R., have recently evolved such a process, of which a demonstration was given recently at their station at Bulstrode in Bucks. The process was devised originally to make use of waste organic material produced in the sisal industry, but it has since been found that other waste materials such as groundnut husks, palm kernel husks and other substances can also be used. The materials are ground and treated and the product, which has been patented under the name ' Pectosol,' mixed with an equal proportion of cement is the stabilising material. Laboratory experiments have shown that 3 parts of this material mixed with 100 parts of soil gives satisfactory results.

Water content

In practice it is first necessary to ascertain the optimum water content for the particular soil to be treated. The soil is then tilled with a rotary tiller to a depth of about 6 in. and, after it has been thoroughly broken up, about 3 per cent. of the ' Pectosol '-cement mixture is incorporated in it. The necessary additional water is added and the roadway rolled and sealed with a fluid bitumen or tar emulsion, at the rate of 1 gal. to 7 or 8 sq. yd. of road surface. A carpet of gravel or rough ballast is then laid, rolled and again sealed. It is estimated that under British conditions the cost works out at 3s. per sq. yd.

In the demonstration, soil and overburden from local sandpits was treated in the manner described and within an hour the surface was able to carry medium traffic.

It is reported that the method is under trial in East Africa and West Africa and, if the experimental results are borne out by further full-scale trials, it may well be that it will prove a valuable addition to the means of solving the problem of providing efficient and cheaply constructed roads on agricultural undertakings.

Farm Machinery

Mechanical Maize Picking in Southern Rhodesia

AS an indication of the manner in which farmers in Africa are increasingly turning their attention to mechanisation to overcome labour shortages, the following account of a recent demonstration of mechanical maize pickers at the Gwebi Experimental Station of the Southern Rhodesian Department of Agriculture is of interest ; it has been abstracted from a recent article in the *Rhodesian Farmer*. Three types of maize picker were demonstrated, all of American manufacture. Two of the machines were of the single-row type and tractor-drawn, the third was a self-propelling unit for reaping in double rows.

Mr. J. K. Chorley of the Rhodesian Department of Agriculture, who addressed the farmers at the start of the demonstration, mentioned that maize production at Gwebi had been mechanised in all its stages. It was therefore only logical that the reaping of the crop should also be done by machine.

Opinion after the demonstration acknowledged that mechanisation of the country's main crop was inevitable; more proof, however, was wanted of the ability of the machines to cope with conditions ; obviously big savings in time and labour could be achieved by mechanisation, but a number of modifications would be necessary before they could reach maximum efficiency under Southern Rhodesian conditions. The pickers could clear the fields quickly, thereby eliminating risk of loss through white ants, and they could enable much labout to be saved. For one of the machines it was claimed that the two-row picker type could deal with 20 to 30 acres in an eight-hour day.

Certain difficulties, however, appeared; at Gwebi the maize is planted in 6-ft. rows with two plants every 18 in., whereas in the United States the standard spacing between rows is 40 to 42 in. and only one plant every 18 in. Under these circumstances all the machines worked at double pressure.

Another difficulty was the difference in moisture content of American and Rhodesian maize at the time of reaping. In America maize is reaped at a moisture content of 18% and the maize subsequently dried in special driers. In Rhodesia, on the other hand, maize is allowed to dry to 12½% in the field before picking and there seems to be some danger in these conditions that the cobs would snap and the brittle plants tend to foul the machine.

Actually the maize at the Gwebi demonstration was of 20% moisture content and was thus suitable for machine-picking. It was not clear, however, how the machine would perform with drier maize.

Mr. D. E. McLaughlin, Chief Agriculturist of the Rhodesian Department, explained that it could be dried in maize cribs. He also explained that for the machines to operate efficiently the maize must be planted mechanically so as to ensure equal spacing. Next season hybrid seed would be available to farmers and this should eliminate many of the commoner faults of ordinary farm seed. One big advantage of using pickers would be that farmers who were short of labour but who had surplus land could plant a bigger acreage and thus increase production in the colony.

The Minister of Agriculture, Mr. P. B. Fletcher, remarked that the demonstration provided an opportunity for co-operation between farmers and the manufacturers of agricultural machinery, as a result of which it should be possible to advise manufacturers on the modifications in the machines which were needed to suit them to Rhodesian conditions.

There seems to be little doubt that the use of mechanical maize pickers in Rhodesia is likely to extend and that in due course the obstacles in the way of the complete mechanisation of the crop will be overcome.

The blade raised for hedge cutting

Blade lowered for tree or sugar cane cutting

A Hedge Cutting and Trimming Machine

A MACHINE for hedge cutting and trimming which, it has been suggested, might also be used for reaping some types of crop, notably sugar cane, was first exhibited at the Royal Show in 1948 and an improved model has recently appeared under the name of the Rapidcut, Mark II, which incorporates certain improvements on the original design. It is intended to be mounted on a tractor and is attached thereto by means of a mounting frame which is easily fitted. It is made to be fitted to either the Standard Fordson or the Fordson Major tractor.

The machine itself consists of three main structures : (1) main frame, (2) sliding carriage and (3) adjustable jib.

These are built up of steel angle and ' U ' section channel and give a rigid structure of great strength. The sliding carriage is located on to the main frame on eight rollers, provision being made for the carriage to be traversed outward for a distance of 2 ft. The adjustable jib is secured to the frame of the sliding carriage by two trunnions, about which it can be swung through an angle of 60°. At the outward end of the jib two adjustable forked brackets are fitted and the outer fork carries the blade, driving shaft and hub assembly. Each of these two brackets is provided with eight setting holes and a retaining pin, which give adjustment to the angle of the cutting blade in stages of 10°. Thus the blade can be set from the horizontal position close to the ground up to the vertical position. In conjunction, the jib can be lifted to an angle of 60° and any cutting height can be selected from ground level to 9 ft.

The cutting blade is driven by means of a primary shaft and a secondary shaft ; the speed is 1,000 r.p.m. with the engine speed at 1,200 r.p.m. The cutting blade consists of a steel disc 3 ft. 2 in. diameter, $\frac{1}{4}$ in. thick, on the periphery of which are four ground-cutting edges equally spaced. These cutting edges are $1\frac{3}{4}$ in. long and have a negative rake of 30°. The mountings of the tractor are designed so that the cutting edges of the blade operate through an arc of 180°. The cutting edges are maintained by filing and finishing with a carborundum stone. Having regard to the conditions under which the blade may be working, it is not unusual for the cutting edges to be buckled if a solid object is struck, such as a stone or rock. The ductility of the material is such that it is quite a simple matter to hammer the blade straight. The cutting capacity of this blade is from the lightest grass up to 4 in. diameter growth. For cutting thicker material the 36-in. saw blade can be supplied, and this can be used for clearing rough and heavy growth with the tractor running in low gear. For tree felling the blade is set in the horizontal position and the tractor is driven to a suitable position near the tree. The blade is then fed into the tree by means of the sliding carriage.

There are three lengths of jib available. With the standard jib fitted, the distance of the cutting blade from the outside edge of the rear tyre is 6 ft. 6 in., the 90-in. jib 7 ft. 6 in., and the 102-in. jib 8 ft. 6 in. Lowered to the ground, this reduces the above dimensions 2 ft. in each case. All three jibs are interchangeable. The machine can be turned to bring the jib to the front of the tractor, facilitating driving the tractor to and from the site of operations.

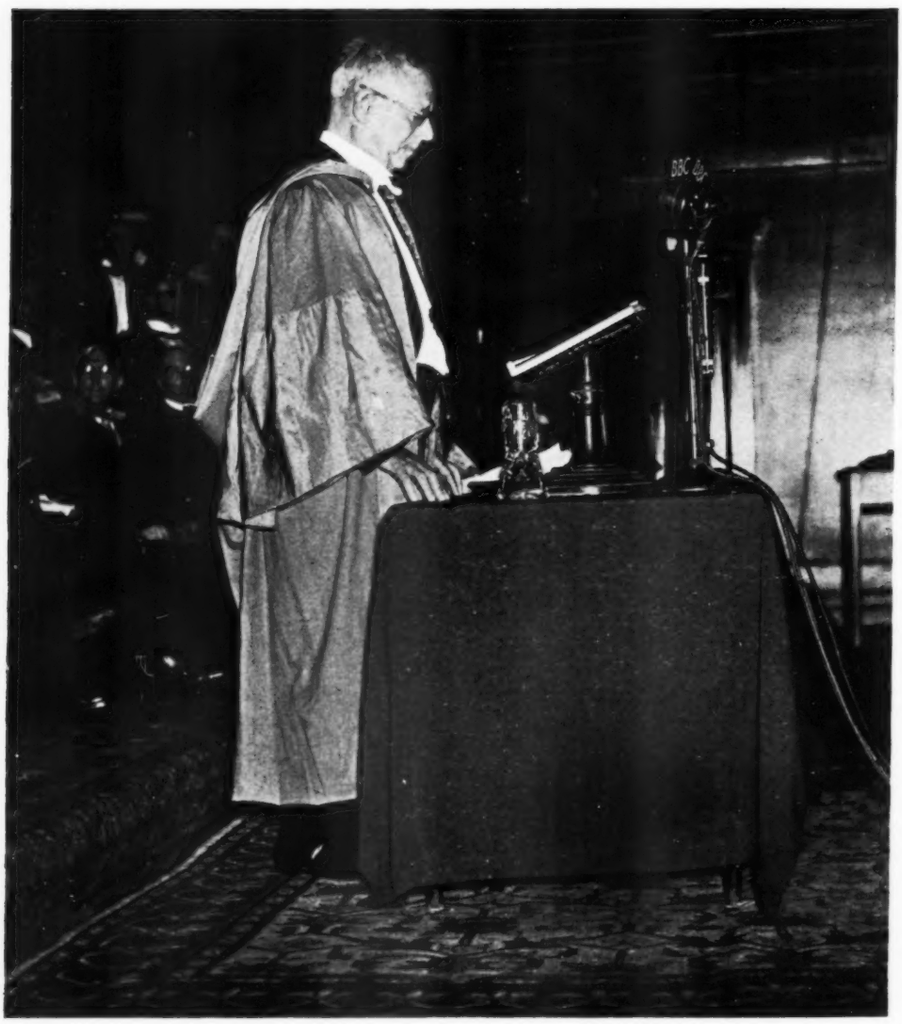
FRUIT SPRAYING. *In connection with the visit to Grove Farms Ltd. at Harwell, briefly reported in the article on the Congress of Crop Protection in our last issue, the photographs above and below illustrate the operations reported therein. They show, above, the Autoblast sprayer spraying fruit trees, and below, the Tifa fog applicator doing similar work*

SIR JOHN RUSSELL

British Association President, examines

The World Problem of Increasing Food Supplies

The world population of 2,300,000,000 is increasing at the alarming rate of some 20,000,000 a year. If all these are to be fed, radical improvements must be made in present methods of agriculture. In his address to the British Association at their recent annual meeting at Newcastle, the President summarised the problem under three heads—extension of the food producing area, more intensive cultivation of the area now being used, and reduction of the present heavy wastage and losses. The progress being made and the measures still to be taken are described in the following extracts from his address.



THE world's total land area is 35,700 million acres, but only about 11,000 million are estimated by C. B. Fawcett to be 'climatically suited' to crop growth. Much of this, however, is at present impracticable for cultivation, and the area actually used is ome 3,000 to 4,000 million acres: 7 to 10% only of the world's land surface. Some 85 or 90% of this area is used for food production; the rest is for industrial crops. The food-producing area represents a world average of about 1¼ acres per head which, at British yields, would give the British pre-war dietary; much less would suffice for a vegetarian dietary. The area 'climatically suited,' however, is about 5 acres per head. Can any of those unused 3½ acres per head be brought into cultivation?

Agriculturists have long been engaged in widening the zone of cultivation by converting the marginal regions of their day into farm land and then pushing out into new marginal regions. The pioneers began in the coastal regions of North America, Australia and New Zealand, where conditions resembled our own, using methods that had been very successful here. Wheat was their main crop. But in pushing inland they were brought to a standstill by the diminishing rainfall, and in Canada the early onset of winter; everywhere their crops suffered from pests and diseases. In 1898 Sir William Crookes, in his presidential address to this Association, startled the world by declaring that the process of expansion was nearly over and by the 1930s the world would suffer hunger unless yields were raised. He showed how the necessary nitrogenous fertilisers could be prepared synthetically from the nitrogen of the air. This address was one of the most momentous the Association has ever heard; it founded the great nitrogen industry and everywhere stimulated agricultural investigators to fresh efforts.

The wheat problem was solved, but not in the way Crookes expected. Shortly after his address the new science of plant genetics was founded and for the first time it became possible systematically to transfer characters from one plant to another and so obtain new varieties possessing certain desirable qualities. Early ripening, shortness of straw and a high ratio of grain to leaf are all required in drought- and frost-resistant varieties, and all are heritable characters, as is resistance to rust and other diseases. Worldwide search was made for varieties possessing the desired genes, pure line and other techniques were evolved, and new varieties were in time produced suitable for the marginal regions so that these became productive farm lands. By the 1930s Canada's 1898 wheat acreage of

4 million had risen to 27 million; Australia's 5 million to 16 million, and Argentine's 7 million to 20 million; the world acreage and output rose far beyond the limits set by Crookes, and there was such a glut that wheat growers everywhere suffered greatly.

Since the 1930s, however, the wheat area of these new countries has not expanded, which has been taken to show that no more new wheat lands are available. The deduction is unjustified. Agricultural development of new lands is very costly, requiring development of transport, storage and marketing facilities, and it is not undertaken unless a profitable market for the produce is assured. The glut of the 1930s had a restraining effect on development. Even the war has not stimulated much expansion. In 1940 Canada raised her acreage to 28.7 million in response to our urgent appeal, but the difficulties of disposal caused such discouragement that in 1941 the area fell to 21.9 million acres, and even now is only about 24 million acres, this being all that present conditions justify. All the same, Canada was able last year to supply three-quarters of our imports of wheat and flour.

Use of marginal land

A new and very promising attack on the marginal lands is now being made. It is the soil-climate complex, not the climate alone, that determines agricultural use. The climate factor may be beyond our control but the soils are being improved. Marginal lands are generally used for ranching—often many acres to one animal. Their present use is for low-productive ranching onlv. The more tractable are being converted into properly managed grazing land. The approach is ecological; the vegetation is surveyed, the types classified, methods of management and conservation are worked out for each type. In South Africa over 100 different types of veldt are recognised, each requiring its own system of management. Seeding with better grasses is being widely practised, particularly in the United States; the world is ransacked for suitable types. Unfortunately some of the good drought-resisting grasses do not easily form seed under cultivation, though they do so readily in their wild habitat. The cross-breeding of the semi-arid types has hardly started.

In view of the very great importance of grass for soil conservation in all parts of the Commonwealth, it is highly desirable that a well-equipped Commonwealth station should be established to study existing semi-arid types and produce new ones. One of the great needs now is for leguminous plants that will do for the semi-arid and tropical regions what subterranean clover and lucerne have done for the moister regions.

Large tracts of land hitherto unfertile are gradually yielding up the secret of their barrenness. Australia has made great progress. In large parts in the south the cause was the lack of trace elements: zinc, copper, molybdenum and others; these being supplied, the soil under proper management became productive. In the attractive Albany region are 300,000 acres to be made into 400-acre farms. For the large parts in the north, however, the secret is not yet discovered, nor has it been for the 300 million acres of peat and muck soils in Canada. But in both countries and also in New Zealand competent scientific workers are studying these problems.

The wheat belt which once stopped at about the line of 18-in. annual rainfall, now stretches to the 12- or 15-in. line (dependent on the evaporation), and the utilisable grass belt down to the 8- or 10-in. line. There are, of course, difficulties in developing regions of erratic rainfall, particularly the problem of storing the surpluses of good years for use in bad years, but these should not be insuperable.

The hot regions of the world present special problems because they can never be closely settled by white people. Australia's empty north has vast areas of natural grass land with adequate rainfall for beef production, and bulldozers have revolutionised the making of dams for water storage.

A chilling process based on the low-temperature research at Cambridge can now replace the old unsatisfactory freezing technique whenever the quality of the beef justifies the cost. The possibilities of arable cultivation have been greatly increased by the development of the disc plough and other implements; the Overseas Food Corporation is proposing to develop 315,000 acres of Northern Queensland, mostly for arable crops, including sorghum varieties suited for mechanised culture.

Africa's problems are fundamentally different. The small native peasant is already in occupation with his own traditional ways of life. Yet he alone can supply some of the products vitally important to us—oil seeds, fibres, tea, coffee and cocoa. The problem is to replace his primitive methods by modern efficient methods without too great a disturbance of the best elements in the native life. We may be justly proud of the splendid pioneering work of the British agricultural offic rs; this country has done more than any other for the opening up of Africa. The Sudan Plantation Syndicate has for many years been highly successful in combining modern scientific cultivation methods with a way of life acceptable to the native and justifiable before the bar of civilisation. In West Africa progress has gone so far that mechanisation can now be introduced into the native community farming. As in Australia the bulldozer's remarkable power of scooping out 'water holes' promises greatly to facilitate development. In Central and East Africa scientific workers at Amani and in the Departments have paved the way for the huge scheme of developing $3\frac{1}{4}$ million acres of savannah land, hitherto empty because of the tsetse fly and lack of surface water—troubles now capable of reduction.

The wet tropics (50 in. or more rainfall per annum) contain more unused land than any other vegetation region in the world. Sir Harold Tempany has discussed the possibilities of the British portion; the Belgians have done much useful work in the Congo; and U.N.E.S.C.O. proposes a survey of the vast forest basin of the Amazon. Dr. Kellog and other American experts are hopeful about the utilisation of part of these regions.

At the other end of the temperature scale lie the cold leached soils of the northern latitudes, the podsols, naturally under coniferous forest but brought into cultivation as need arises. The Finns—the most northerly farmers of the world—the Canadians and the Russians are all studying the problems involved, while the Swedes, at their incomparable station at Svalof, have produced varieties of arable crops well suited to the conditions.

But we need not go abroad for marginal and waste land; we have plenty at home; this also can be reclaimed by conversion first into grass land, then if need be into arable.

In short, wherever cultivation is now practised, there are possibilities of extension and no one can say how great they may be.

Soil erosion

Against these potential gains, however, must be set the very serious losses due to soil erosion.

In Africa great losses have long resulted from uncontrolled burning and over-grazing the grass lands, exposing the bare soil to the beating of the torrential rains characteristic of semi-arid regions, washing it away and often leaving great gullies. It was the dust storms of the dry 1930s in the United States, and in particular a terrifying one on May 16, 1934, that made all America aware of the 'Dust Bowl' and the need for drastic action. In the United States some

330 million acres out of 460 million acres of good arable land were estimated to have suffered, as had something like half of the wheat land of Australia, great areas in Africa, Asia and elsewhere.

The United States was the first to act and set up very successful soil conservation services and a superb model: the Tennessee Valley Authority.

It is now recognised that erosion comes about through wrong use of the land, and the remedy is correct utilisation, both of land and of water, applied over the whole catchment area. The problems are therefore not exclusively technical but administrative also. A vegetation plan must be drawn up to ensure continuous cover of critical areas—hilltops, slopes, etc.—with trees or grass, and the protection of arable land against soil movements and run-off of water by mechanical devices such as contouring, alternate strip cultivation, etc. For full effectiveness the plan requires the collaboration of the ecologist to ascertain what plant combinations are most appropriate, the agriculturist and forester to select those of most economic value, and the plant breeder to narrow the gap between the ideal plants and those actually available. Grass plays a vitally important part; it not only covers and protects the soil but builds up the fine particles into crumbs by processes not yet understood; successful treatment largely depends on the selection of the right grasses, particularly rhizomatous or stoloniferous types. A large amount of successful conservation has been done and much eroded land has been rehabilitated in the U.S., Canada, Australia and Africa.

Soil erosion could be dealt with much more easily if the problems were solely technical; unfortunately, the need for recasting the vegetation of a whole catchment area often cuts across all sorts of social or tribal customs, personal or sectional interests, political boundaries, etc., and raises many complex administrative problems. A few recalcitrant objectors could spoil the whole plan; it must be enforceable by law, but voluntary co-operation of all concerned should be the aim.

An elaborate plan has been drawn up for dealing with erosion in the U.S.S.R. In most other affected countries, except perhaps China and parts of South America, the need for control is recognised and the lines of action laid down.

Intensification of cropping

The most hopeful way of increasing world food supplies is by more intensive cultivation of the land already in use. It is especially important for Asiatic and African peoples—60% of the world's population —for they have no prospect of emigration and very little of food imports from other continents. Their present product is chiefly grain, the yields low and uncertain, the methods inefficient. Experimental farms in India commonly obtain twice the yield of the neighbouring peasants, and there is often no physical reason for the disparity. But the difficulties of levelling-up are enormous; they spring from the peasants' poverty, their overflowing fecundity and the consequent minute subdivision of the land; these can only slowly be remedied.

Meanwhile, some improvement is possible. Irrigation can still be considerably extended. The projected Nile schemes, if realised, will solve Egypt's problems for a generation, while Asia, which already has some 70% of the world's irrigated area, mostly in the Himalayan region, can greatly increase the area served by tube wells as developed by Sir William Stampe.

Scope in Asia

Asia also offers vast scope for fertiliser use. Rice is the crop most affected; it is perhaps the most crucial crop in the world. It has been much studied in India and improved varieties have been raised by pure line selection; hybridisation is hardly begun. Nothing would more greatly increase its output than wider application of nitrogenous fertilisers. But rice is mainly a swamp crop and ordinary methods of fertiliser use break down. Nitrate of soda is relatively ineffective: sulphate of ammonia often acts well but sometimes not. These puzzling complexities were resolved from a quite unexpected quarter. Prof. Pearsall, in studying marsh conditions in Cumberland, found measurable differences in oxidation—reduction potential in the water-logged soils; oxidation took place at the soil-water surface but reduction lower down. Directly they heard of this, the Japanese experts saw its bearing on the rice problem. Sulphate of ammonia put on the surface of the mud in the usual fashion, at or before transplating, was quickly oxidised to nitrate which washed down below and was reduced to gaseous nitrogen. But if the sulphate of ammonia was pushed down through the oxidation zone into the region of reduction it lay safely till the plant roots took it up. If nitrates, e.g. ammonium or sodium nitrate, are added during the period of rapid growth they can be absorbed quickly before they reach the reducing layer; therefore they may be used as later top dressings. The study of these oxidation and reduction zones showed also how cyanamide and other fertilisers should be applied. It gives for the first time a scientific basis to the manuring of the rice crop; another example of the far-reaching results that may come from a purely academic enquiry well carried out.

The human problems are more difficult. Will Burma under her new management retain her leading position among rice exporters? And can Siam and Indo-China produce as efficiently as before? How will India fare if they do not?

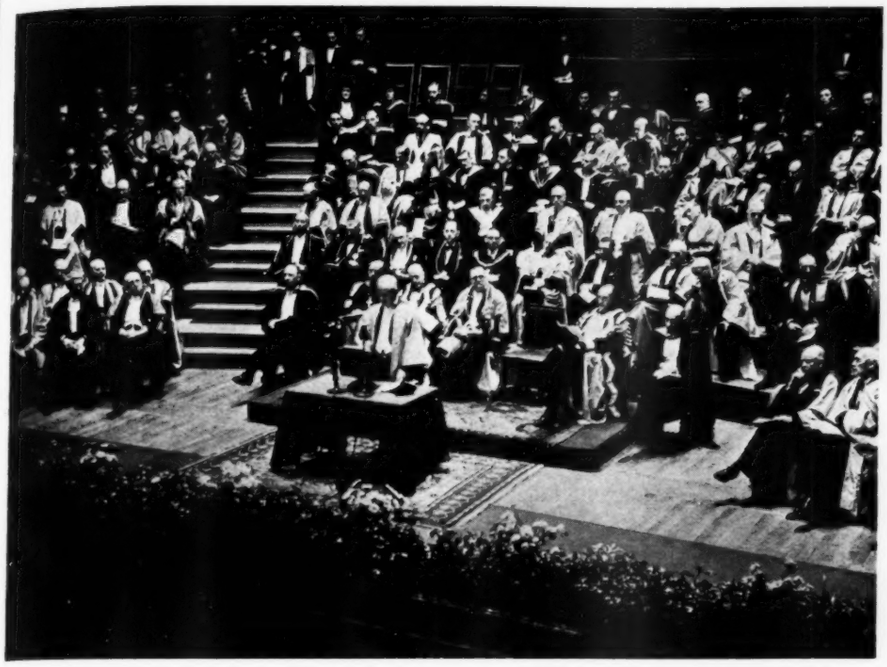
The millets are specially important as native food in the semi-arid regions of India and Africa. We have done less work on these than we should, but this is to be rectified in the East African research scheme.

The general methods of intensification of food production are the same everywhere. Land tenure and size of holding usually need modifying to encourage higher efficiency: the holding should be of such size that one man can adequately supervise it. More productive systems must be evolved, and bare fallows replaced by tilled crops and by grasses and leguminous plants. Inevitably there comes a development of livestock. In the highest and most productive systems livestock products yield far more income than cash crops; before the war our livestock accounted for 70% of the value of our farm produce and, according to Leitch and Godden's estimate, consumed on the average about 100 million million calories per annum (just about double the consumption of all our human population) and giving us in return less than 10 million million calories. But it is only fair to say that they supply other essential needs, that most of the foodstuffs they consume are useless to us, coming from grass, straw and various industrial and other residues; and that they greatly enhance the productiveness of our soils.

Intensification is greatly facilitated by the adoption of some form of farmers' association allowing joint and economical use of complex appliances, buying and selling operations, etc.

Chief among the intensification methods is the improvement of the soil by fertilisers, lime, drainage, etc. Fertiliser requirements are ascertained by chemical analysis and by statistically controlled field trials or by foliar diagnosis and plant analysis. Trace elements are studied by spectroscopic methods.

Happily the necessary fertilisers are producible in almost unlimited amounts; the nitrogen comes from the air to which in due course it returns; the known deposits of phosphate are estimated to suffice for some thousands of years at present rates of consumption; those of potash are also abundant. Much more fertiliser could



The general scene at Newcastle when Sir John Russell delivered his presidential address

advantageously be used if farmers' means permitted. A better fertiliser supply and more leguminous cropping would quickly raise output over large parts of the world.

Along with more fertiliser goes the need for better seeds and better varieties; here the British farmer is particularly fortunate.

But all improvements fail unless weeds—arch-enemies of mankind—are adequately controlled. Their destruction is one of the chief tasks of arable farming; chemical methods are coming in but cultivation is the standard method; this and the preparation of a seed bed are usually its main purposes.

Perhaps the most significant changes in modern farming have been the increasing mechanisation and the alacrity with which the younger farmers have accepted it. Tractors are displacing working horses—perhaps too rapidly.

In Great Britain, despite additional power and machinery, annual output has been below the war-time peak, while the total labour force on farms, allowing for changes in composition, has remained well up to war-time strength. Clearly there is room for more economical use of farm power.

It is impossible to forecast what the tractors of the future will be like; the United States already has some of 140 h.p. The limit is likely to be set by the amount of oil fuel available; the French foresee a shortage and are starting experiments on the production of methane by fermentation of straw. Tractors require their own special implements, which must be generalised and mass produced to keep down their cost; they can no longer be made by local craftsmen to suit local requirements like the old types; their manufacture is shifting to the industrial regions of the Midlands and Yorkshire—Canadian and American firms are recognising the possibilities.

These engineering developments are enabling farmers to cope with the ancient difficulty that Nature's production of food is by jerks, while consumption is fairly steady. Storage is therefore necessary; usually it has to be done on the farm and it is often attended by considerable loss. Grain crops may suffer from rats and mice; these are estimated to destroy 2 million tons of food annually in England and Wales alone. Grass, our most important and for long most neglected crop, when made into hay commonly loses 30% or more of its valuable protein equivalent; but in any case haying is inapplicable for modern intensively managed leys or lucerne that give three heavy cuts of highly nutritious material a year. Artificial drying preserves the nutrients intact; it requires 10 to 15 cwt. of coke per ton of product; 3 tons of dried grass per acre can be obtained—three times the old average yield of hay. Ensilage is cheaper, but involves loss of 20 to 30% of the nutrients; lack of driers makes it at present the more practicable alternative.

Increased intensification necessitates strict measures against pests and diseases, which now travel widely and are favoured by the greater crowding of crops. Resistance is fairly frequently a heritable character and, once the genes are found, resistant varieties can be produced such as the rust-resistant wheats of North America and Australia and the potatoes bred at Cambridge and at Corstorphine. The pathogen may exist in several strains, necessitating the introduction of several genes. The work is never ending, for a relatively harmless organism may suddenly change, like the *verticillium* which, having long lived an almost blameless life in the Kentish hop gardens, about 20 years ago suddenly produced a virulent mutation which has since done much damage there.

New insecticides

Measures for protecting plant and animal health are being steadily improved. Plant virus diseases still defeat us, but the able and persistent efforts of F. C. Bawden, N. W. Pirie, Kenneth Smith and others cannot fail to bear fruit. Against insects the new chlor- and phosphorus-insecticides are very potent and methods of spraying have greatly improved; even wire-worms, long invincible, have succumbed to hexachlorbenzene. But there are always risks in interfering with Nature; the D.D.T. which was so effective against codling moth in orchards, also killed the insect that had kept in check the red spider, and this not being affected by the D.D.T., became in its turn a pest.

Animal diseases—to which we are very liable because of our large imports of animal carcases—are steadily being brought under control. The old method was instant slaughter to avoid spread; it was effective but costly. The modern method is to apply diagnostic tests so as to catch the disease early, then to segregate and give the appropriate treatment.

Wheat yield in U.K.

Most countries could increase their food production considerably by applying known methods of improvement and raising the average performance to the level of the best. The yield of wheat in Great Britain used to be about 8 or 10 cwt. per acre; it now averages 20, and the best farmers get 30 or 40, but the world average is only about 7.

The old agriculture could be carried on by appliances made by local craftsmen. Modern intensified agriculture cannot; it demands high-grade machines, chemicals, sources of energy that only a highly-developed industry can supply and, of course, corresponding standards of education among the farmers.

We in Great Britain, from our present small and shrinking allocation of land, may yet raise half our food, besides improving the quality of both meat and milk.

And the less developed countries can feed their people better than they now do.

Scientific aids to food production

Pure science is continuously opening up new possibilities for use in agriculture. The starting point is commonly some purely academic problem of no apparent practical interest whatsoever.

One of the most fruitful series of investigations began with the old enquiry: Why do plants turn their leaves towards the light? Went and Kögel at Utrecht showed that the response was due to minute amounts of an organic compound which operated by causing growth of the tissue where it happened to be. Several of these growth promoters were found. They are called auxins and have a fairly simple chemical pattern—a straight-chain acid group combined with a benzene, naphthalene or indolyl group, indole-3-acetic acid being one of the commonest.

These and similar substances were soon prepared on a large scale and were shown to promote root formation in cuttings: Zimmerman and Hitchcock at the Boyce Thompson Institute investigated the action in detail and horticulturists used it in practice. Later it was found that these auxins induced the setting of fruits of the tomato and cucumber family without the intervention of pollen from the male organ. A spray of β-naphthoxyacetic acid, 40 p.p.m. of water, has been used considerably by commercial growers; the fruits are normal in appearance but not yet in quality, and they are seedless.

So far no substances have been found effective for large fruit trees, except some varieties of pear.

It was naturally expected that auxins might increase seedling growth, but they did not, even killing some but not others. Cereals were much less injured than some of their common weeds, and selective weed killing became a possibility.

Others of these compounds are used for checking growth; preventing potatoes from sprouting in storage; staggering pineapple harvests in Hawaii to fit the canning facilities; preventing the pre-harvest fall of apples, etc. Other substances change vegetative shoots into flowering shoots. No one can see the end and, I repeat, it all started with the purely academic enquiry: Why do plants turn their leaves to the light?

Various soil organisms are known to produce antibiotic substances, analogous to penicillin and highly destructive to certain other organisms. Thaysen and others have found in tropical soils bacteria with high powers of inhibiting the growth of fungi. In the absence of a good soil fungicide it is possible that soil-borne fungal diseases such as ' Take-all ' disease of wheat and Panama disease of bananas might be successfully controlled by introducing or encouraging organisms producing the appropriate antibiotic. Bacteriophages, destructive to various bacteria, are also known to exist in soils, though they have as yet found no application in agriculture. Add to this list the large number of protozoa, acrasieae and giant rhizopods found in soil by B. N. Singh and other Rothamsted workers, and shown to feed on bacteria and other soil organisms, and it is clear that life within the soil is as full of risks and of possibilities as life on the surface. Some degree of control of this vast soil population so vitally important to soil fertility has long been sought, and the older method of partial sterilisation may in due course be supplemented by newer agencies.

Algae and fungi

Some of the algae and fungi, especially the yeasts, have remarkable power of synthesising fats and proteins. Only limited use has so far been made of this property but the possibilities are considerable.

Moreover, there still remain unknown possibilties in the oceans, for they carry much more vegetation than the land.

Genetical science can still do much more to help crop production. To give only one instance: wide crosses often produce sterile off-spring. But treatment with colchicine in some cases doubles the chromosome number and makes the off-spring fertile. New types can thus be synthesised which can be used for producing new economic forms.

Many of the vital processes in animals are, like those of plants, determined by chemical substances, and some degree of control has already been attained. H. D. Kay, at the Dairy Research Institute, Shinfield, has shown that thyroxin injected subcutaneously, or iodinated protein (casein) fed by mouth, increased the fat content of the milk and also raised the yield up to 20% after the peak of lactation was passed. Even more dramatic was the use of a synthetic oestrogen, diethylstilboestrol, introduced in tablets under the skin, for inducing lactation in virgin heifers or barren cows—the first stage in making the male redundant.

Artificial insemination is already widely used and is rapidly spreading, especially for dairy cattle, as milking capacity is largely inherited from the sire.

However, it is a fact that attempts to control natural processes without adequate knowledge are always risky and may be dangerous. And so agricultural scientists have long aimed at knowledge rather than control, certain that if their knowledge is sound, their control will be secure. In the great agricultural research institutions today ideas and equipment are freely borrowed from the pure sciences. In studying soils, plants, animals and their relations one to the other, use is made of modern biochemical methods, physical methods, *x*-ray photography, the electron microscope, tracer elements to follow the processes of plant nutrition, and so on.

I shall attempt no forecast as to how much food the earth could be made to yield. The limit at any time is set by the efficiency of the plant as a transformer of radiant energy; at present this does not exceed 5% and, reckoned on the basis of the amount of food produced, it is much less. Whether this can ever be raised, whether we can ever do more than increase the proportion of assimilation products useful as food, cannot be said. But the present limitations to food production: utilisation of 7 to 10% only of the earth's surface; conversion by the animal of 10 to 25% only of its food into human food; and fixation by the plant of no more than 5% of the radiant energy it receives—these are all challenges to agricultural science, which its workers are vigorously taking up.

First U.S. Wheat Sold Under World Agreement

A total of 6,034,031 bushels of wheat and wheat flour was sold by the United States to importing countries in the first 18 days since marketing began under the International Wheat Agreement on August 1, the U.S. Agriculture Department has reported.

More than two thirds of the total—4,265,341 bushels—was sold in the week August 12-18. (A U.S. wheat bushel is 60 lb.).

Countries which bought the wheat are Belgium, Ireland, Israel, the Netherlands' colonies, Norway, Peru, Portugal and Portuguese colonies, Saudi-Arabia, United Kingdom colonies and Venezuela.

Under the wheat agreement, the United States is committed to export about 168,000,000 bushels annually for the next four years, in return for a guaranteed export market. With guarantees of three other exporting countries—Canada, Australia and France—the total scheduled for export is 456,000,000 bushels.

By August 1, 19 countries had ratified the agreement, which is intended to help stabilise the world price of wheat. Other countries have signed the agreement and they will be able to take part in the marketing programme if they ratify the accord by the end of October.

Radioactive Tracers in Agricultural Research

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THE production of artificial radioactive isotopes has resulted in a spectacular addition to the methods of the research worker. In almost every field of science their value is being actively explored, but it is perhaps in biology that their use as ' tracers ' open up the widest new vistas. The word ' tracer ' explains exactly the manner in which the biologist employs them. He is not interested in isotopes for their own sakes ; he uses them to ' label ' normal non-radioactive substances which he can then detect by the radiation emitted. By this means he is able to observe processes of many types which hitherto have been impossible of direct study.

The object of this article is to indicate ways in which radioactive tracers can be used in the elucidation of agricultural problems. Before doing so it is necessary to consider the physical nature of isotopes and the ways in which they can be identified, for on this depends their value to the biologist.

Isotopes

It has been known for many years that a single element may exist in more than one atomic structure. Some elements—potassium, for example—always occur in nature as mixtures of isotopes, as these different atomic forms are known. The isotopes of an element differ one from another in that their nuclei have different masses ; they have the same chemical properties because they have the same numbers of electrons in their outer orbits. The atomic structure of many isotopes is unstable—sooner or later each atom of such an isotope undergoes a sudden transformation, turning into another substance and emitting radiation. A simple example is the disintegration of radioactive phosphorus (phosphorus^{32}) which emits an electron and becomes sulphur. The time at which any atom of one of these unstable or radioactive isotopes will discharge its radiation cannot be predicted, but the *average* rate of breakdown for any isotope is constant. Thus the ' half life ' of an isotope—the time taken by half the atoms in a sample to break down—can be determined.

The use of radioactive isotopes as a means of tracing the changes which take place in plant nutrition opens up a new and fascinating field in the sphere of agricultural research. It seems extremely probable that with this new tool scientists will in due course be able to throw a flood of light on many of the problems of crop nutrition which are at present obscure. The scope and the potentialities of this new technique are described and discussed in the following article.

(Photo : U.S. Dept. of Agriculture

" Tagged " or radioactive fertiliser is here shown being loaded on the endless belt of the hoppers of a fertiliser distributor. Operative on left is checking radiation hazard with a safety meter as the radioactive material is poured out through a metal tube

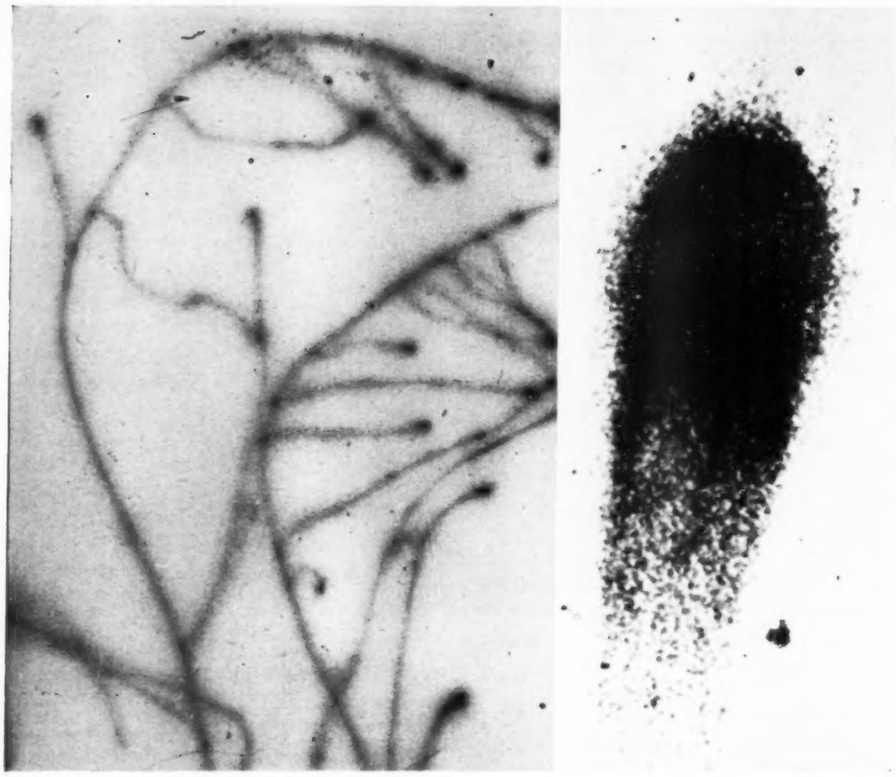
Only radioactive isotopes of long half lives occur naturally on the earth. The production of radioactive isotopes by cosmic or other natural radiation is at the present stage in the earth's history minute though still measurable. The radioactive isotopes that occur in significant quantities are thus necessarily long lived or the derivatives of long-lived radioactive substance, otherwise they would not have survived from the earth's remote past. Radium—with a half life of 1,600 years—is the best known example. It is formed by the breakdown of uranium which has a half life of over a thousand million years. Using naturally occurring radioactive isotopes, Hevesy carried out the first tracer investigations over 25 years ago. However, the scope of the work was necessarily limited by the lack of radioactive isotopes of elements important in plant and animal metabolism.

Tracer methods

The possibility of tracer methods becoming of wide application was foreshadowed by the artificial production of radioactive isotopes in small quantities by nuclear physicists in the years before the Second World War. Atomic energy research during the war brought about the realisation of this possibility with dramatic suddenness. The production in large quantities of many radioactive isotopes was now possible. Among those most useful as tracers in biology are isotopes of phosphorus, carbon, potassium, sodium, iodine, iron, sulphur, cobalt, molybdenum, calcium and hydrogen. These isotopes are not all equally useful as some decay very rapidly and others emit very weak radiation. Radioactive phosphorus which has a half life of 14 days is a particularly convenient isotope. Nitrogen and oxygen do not figure on the list while the isotopes of hydrogen are of limited use because their rate of diffusion is greatly different from that of the normal element.

Labelled substances

If small quantities of a radioactive isotope are mixed with the normal form of the element, the plant uses the mixture which is often called a ' labelled ' substance, in the same manner as the normal element. Thus we can infer the movement of the normal element or ' carrier ' by observing the movement of the tracer. This can be done in two main ways—by electronic methods or photographically. Both are of wide biological application. The Geiger Mueller tube is the most



Radioautographs showing the distribution of labelled phosphorus in young barley plants. Left, root system general view. Centre, tip of a single root. Below, stem apex in longitudinal section. (a) apical meristem (b) leaf primordia (c) points of attachment of leaves (d) initial of adventitious root, cut obliquely. The accumulation of labelled phosphorus is indicated by the degree of darkening on the radioautographs

widely used electronic equipment. Each pulse of radiation which enters the tube is separately recorded and counted if the tube is connected to a suitable scaling circuit. Each pulse of radiation comes from the breakdown of a single atom. Thus the tracer is counted atom by atom as it decays. Only a small proportion of the atoms of an isotope will break down while a sample is being counted and only a proportion of the resulting radiation will enter the counter. Even so, tracer techniques have an analytical sensitivity of an entirely different order from other analytical procedures which can only detect millions of millions of atoms. It has been calculated that if one ounce of radioactive phosphorus were spread uniformly over the entire surface of the earth the amount present on any square inch could be accurately measured. The great value of radioactive isotopes as tracers is partly due to this immense sensitivity and partly due to the fact that the presence of non-radioactive substances in a sample does not interfere with the analysis (except by absorbing radiation and this can be allowed for).

Radioautographs

It is well-known that photographic emulsions are sensitive to X-rays. Similarly they are sensitive to the rays emitted by radioactive isotopes. Thus, if a suitable photographic emulsion is placed in contact with a piece of tissue containing a radioactive tracer, a photograph showing the distribution of the tracer can be obtained—it is called a radioautograph. It is not possible to focus the radiation but under suitable conditions the distribution of an isotope within a single cell can be shown. The accompanying photographs illustrate how the technique can be used to show the distribution of a substance—phosphorus in this case—between different tissues of a young shoot.

Application

Having seen the various ways in which radioactive tracers can be detected we can now consider the types of observation, difficult or impossible by other means, which can be made by tracer methods. They can be summarised under four heads :—

(1) Quantities of substances labelled with tracers which are far too small to detect in other ways, can be readily measured. For example, the amount of labelled phosphorus a root tip absorbs in a few minutes can be determined though the quantity involved may be less than one-millionth of a gram. In the study of absorption from dilute solutions or the utilisation of the minor nutrients—which are always present in very minute quantities—this characteristic of tracer methods is clearly of great value.

(2) A ' labelled ' substance can be distinguished from unlabelled material of the same substance. Both in plant physiological and soil investigations this is of immense value. For example, if ' labelled ' fertilisers are used their fate both in the plant and the soil can be determined. The particular advantage of this method in the study of phosphate nutrition will be discussed later. Again, by labelling the nutrients plants receive at different periods in their life history, the movement of nutrient within them and their changing utilisation, can be followed in a way hitherto impossible. It has, for example, been shown that within a few minutes of entering the root some of the material a plant absorbs has travelled far up its stem to the upper leaves. No other method could provide information of this type.

(3) A further, and particularly elegant, advantage of tracers is that *in vivo* determinations can be carried out on living plants without interfering with them. The movement of substances can be followed by placing a counter close to a plant or animal. Similarly the disappearance of labelled substances from culture media can be progressively followed. Thus on a single individual a whole series of observations can frequently be made.

(4) Finally, as has already been seen, not only can the quantity of a labelled

substance be determined but also its distribution on a submicroscopic scale can be shown by radioautographs.

Fortunately, an alternative tracer method is available for many of the elements which lack suitable radioactive isotopes. By means of the mass spectrometer stable isotopes can be distinguished. The necessary equipment is more complex than that required for detecting radioactive isotopes but its potential value may be gauged from the fact that it has been found possible to identify nitrogen where present in one five-hundredth of the quantity detectable by the micro Kjeldahl method. Carbon and oxygen are other elements which can be studied in this way. It is, however, with radioactive tracers that we are here concerned.

Problems and limitations

All experimental methods present their problems and the more delicate the tool the greater the refinements of technique which are necessary if full advantage is to be reaped from its use. Thus though some answer can always be obtained by placing a sample close to a Geiger counter, a valid answer with real meaning results only when a very careful routine is regularly followed. This is not the place to discuss details of laboratory procedure, but it cannot be too strongly emphasised that the apparent ease of tracer work—provided the electronic equipment is working—can lead to the disastrous conclusion that tracer investigations can be easily undertaken. Careful standardisation and extreme cleanliness are of particular importance ; only too easily can equipment become contaminated.

Biological effects

One fundamental question has, in many types of tracer work hitherto received inadequate attention—the possible biological effects of the radiation. Since the tracer is employed to show the behaviour of normal non-radioactive substance, it is obvious that if the organism is damaged by radiation, the method is valueless. The amount of tracer necessary to ' label ' a culture solution or a plot of soil is so small that the radiation emitted from it is so slight that no damage is likely in a neighbouring organism from *direct* radiation. But both plants and animals absorb substances, accumulating them in high concentrations in certain organs. Iodine is accumulated in the thyroids of animals, calcium in bones, phosphorus and other nutrients in the meristematic regions of root tips. Thus, by the absorption of a labelled substance local centres of radiation sufficiently intense to upset normal metabolic functions can occur. The extent of possible damage cannot be inferred from the amount of tracer applied —it varies with the rate of absorption of the plant or animal.

The more active the organism the greater the probable damage. The length of an experiment also influences the effect. Some important tracer work on photosynthesis has involved experiments lasting only a few minutes—obviously the danger is less there than in nutritional experiments which may last several weeks. Most of the literature of fertiliser studies with plants suggests that radiation effects are negligible—but this, unfortunately, is largely explained by the fact that the majority of workers have studied only the above ground parts of plants. Radiation effects due to absorbed nutrients are greatest in roots. Under some circumstances the weight of roots and the rate of phosphorus absorbtion of the entire plant has been shown to be greatly reduced by radioactive phosphorus, though the weight of the shoots and also their appearance is normal. If this situation occurs the results of a fertiliser uptake experiment are at best worthless and at worst misleading. Thus an essential preliminary to fertiliser investigation is the careful determination of the safe tracer level. Radiation effects set limits to possible tracer work—but they are broad limits. An immense amount of work can safely be done.

Hazards and risks

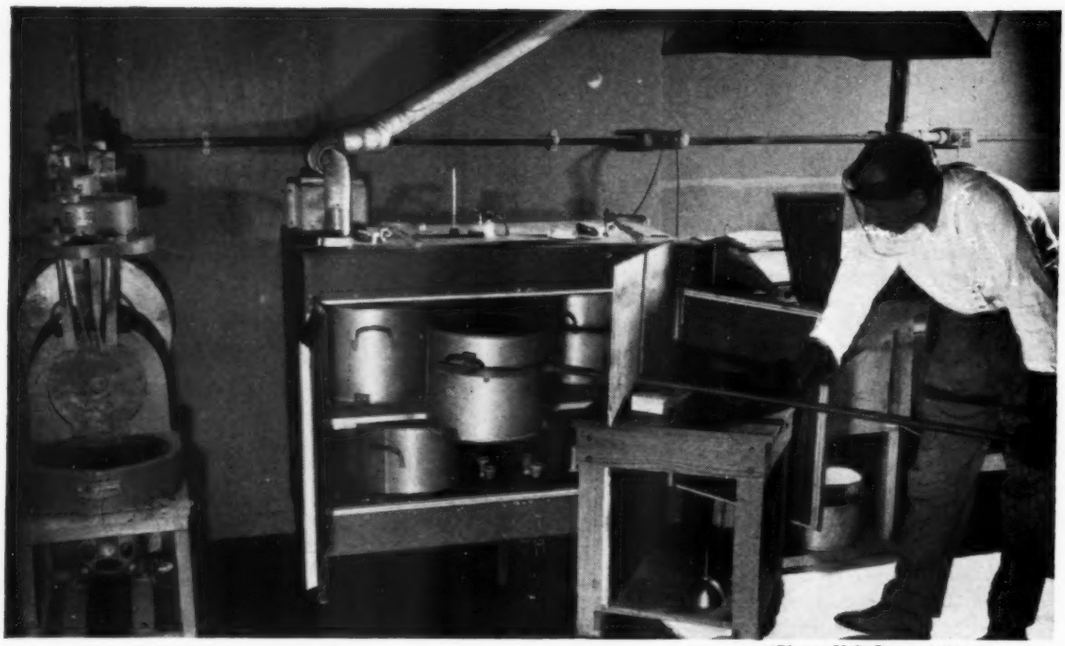
Tracer investigations necessitate complicated electronic equipment and for this reason the biologist must expect a programme of tracer studies to be beset with difficulties if he lacks efficient technical aid. The presence of an electronic physicist in the research team is the ideal arrangement and he has a far greater part to play than that of a mere technician. Organic- and bio-chemists have long since become essential members of biological laboratories studying many types of physiological problems. A similar role belongs to the physicist when tracer work is seriously undertaken.

In all work with radioactive substances rigid health precautions are essential. Their necessary extent depends on the physiological utilisation in the human body of the isotope in question. But at all times a laboratory actively engaged in tracer work will contain potentially dangerous material. The hazard can be rendered negligible if a proper routine is followed—from many points of view it is the same routine as is necessary to prevent experimental samples being contaminated. Thus the obtaining of valid results and the protection of workers are parts of the same problem—a problem varying in difficulty with the type of work in progress, but one which can and must be satisfactorily solved.

Geiger Mueller counter and scaling unit for measuring the radioactivity of a substance, in use at the Radiochemical Centre at Amersham, England

Scope for the methods

Having seen the general method of tracer work we can consider some problems of agricultural research in which tracers hold promise of being particularly valuable. At the forefront of fertiliser problems remain that hardy annual of the soil chemist and plant physiologist—the utilisation of phosphates by plants. Some soils known to be phosphate deficient give negligible responses to added phosphates ; in none do they absorb more than a small proportion of the applied fertiliser. The



Production of radioactive superphosphate at the Bureau of Plant Industry, Soils and Agricultural Engineering of the U.S. Department of Agriculture starts in the acidulator shown on the left of the photograph. In this rock phosphate, sulphuric acid and radioactive phosphate are combined. A can of this freshly mixed superphosphate is being placed into the dryer for curing by the operative. He is protected from the radiation of the fertiliser by a jig with a 6ft. handle to hold the can and by standing behind a lead shield fastened to the movable table. After the superphosphate is cured it is a porous white solid which must be disintegrated to uniform particle size before it is suitable for use in the field

(Photo : U.S. Dept. of Agriculture

remainder is ' fixed ' in the soil. Despite the large amount of time which has been given to this problem, the exact manner of phosphate fixation remains unknown, and methods for preventing or reducing its occurrence have still to be found. This is largely because the amount of phosphate added in fertilisers is always very small by comparison with the phosphate already in the soil. Consequently the resultant changes in soil phosphate fractions cannot with certainty be determined. Fortunately radioactive phosphorus is one of the most readily available and the most convenient to handle of isotopes. Its use is obvious ; ' labelled ' phosphates can be distinguished both in the soil and in the plant from the natural soil phosphate. Results from research of this type are already becoming available. Among the interesting facts which have emerged is that the increased phosphate absorption of plants supplied with fertiliser is not entirely due to absorption of the fertiliser. The more active root development caused at an early stage may result in the plant developing a root system which more efficiently absorbs the soil phosphate. Another aspect of the phosphate problem in which tracers can be used is in the study of placement and granule size, both of which problems are of active interest to farmers, planters and fertiliser merchants in many parts of the world.

In the study of more fundamental problems of plant nutrition radioactive phosphorus also has a large role to play. For example, they make it much easier to study the effect on plant growth of concentrations of phosphorus similar to those in the soil solution of unfertile soils (perhaps one part per million). Our knowledge of the utilisation of other nutrient elements can similarly be increased. Work with radioactive potassium, iron calcium, sulphur, zinc, copper and molybdenum has been commenced or is under consideration in various laboratories.

The rapid and successful development of selective weed killers has led to much research being undertaken on the mechanism of phytocidal substances. They are lethal in such minute concentrations that normal chemical means are inadequate to detect their movement. The possibility of ' labelling ' them with radioactive tracers provides a very promising method for studying their effects. Some work along these lines has been undertaken already in the United States. Information thus gained should be of fundamental value in the development of new selective herbicides.

While this article has of intention been concerned primarily with plants and the soil, parallel developments in the study of animal physiology should not pass unmentioned. Both in basic metabolic problems and in the study of minor nutrient elements, among them copper, manganese and iodine, the value of the technique is becoming clear.

Conclusion

This review has been of necessity, incomplete and provisional. It is barely five years since tracers were first used on a large scale in many types of work, and five years is a very short period in the development of research. The potential advantages of a method are usually more apparent than its difficulties, which can often be assessed and overcome only when a large body of experimental data are available. This applies to tracers as much as to less spectacular techniques. Thus the value of the method cannot be assessed by the results so far obtained—highly important as they are in several fields. Much more significant is the fact that laboratory methods have been defined, difficulties have been recognised and methods for overcoming them have been or are being evolved. In many laboratories scientists have gained sufficient experience to use tracer methods to good purpose.

The tool is new and exciting. People, whether scientists or business men, are attracted to the new and exciting for its own sake. Sometimes they consider inadequately the real value of what they pursue. This tendency has, to some extent, been evident with tracer methods. A careful and objective consideration of the suitability of tracers for any proposed work is, for these reasons, particularly desirable. It is obvious that because of the complexity and expense of the method its use is not justified if results can be obtained as readily and exactly by more conventional means. In many types of work that is the situation. But it is obvious too that radioactive tracer techniques provide the only direct means for investigating important problems of many types. It has been said that they are the most important new biological tool since the invention of the compound microscope. Time alone can tell how true that claim is, but it is already clear that they can be of immense value. Agricultural research, in common with other fields of science, stands to benefit greatly from their development.

World Output and Consumption of Fertilisers

TRENDS EXAMINED AT INTERNATIONAL CONFERENCE

THE Fifth International Conference on chemical fertilisers and chemical products used in agriculture was held in Zurich from August 4 to August 8. Many countries were represented and the leading production associations for nitrogenous, phosphatic and potassium fertilisers and insecticides sent delegates, as did the main scientific bodies of the world dealing with agricultural chemistry. France, Germany, Italy, Belgium, Switzerland and Holland were particularly well represented.

Nitrogenous fertilisers

Figures for production of nitrogenous fertilisers discussed at the conference showed that world production as a whole (excluding the U.S.S.R.) has increased substantially on the pre-war figures; against an output of 2,988,000 tons in 1938-39, production in 1947-48 amounted to 3,286,000 tons and is scheduled to reach 4,047,000 tons in 1950-51. However, the figures reveal that European production fell sharply in the war and post-war periods, having reached only 1,350,000 tons in 1947-48 against 1,858,000 tons. All European producers plan to exceed their pre-war output in 1950-51, with the exception of Germany—scheduled to produce 450,000 tons against 900,000 in 1938-39. Production in the U.S. has been growing in leaps and bounds, however, and the output of 304,000 tons in 1938-39 was tripled in 1946-47, increased to 1,197,000 tons in 1947-48 and is scheduled to reach 1,287,000 tons in 1950-51. Substantial increases in output are also planned in Canada and Chile. A report read at the conference says that an examination of the possibilities of production in the various countries indicated that when ' normality ' was regained, and when new factories are working, a reduction in prices should be possible.

Phosphate fertilisers

Reports prepared on the phosphate fertiliser industry showed that consumption in 1948 of P_2O_5 was higher than in the last pre-war year—4,900,000 tons against 4,300,000 tons. It was also stated that in the last ten years the U.S. had increased its consumption considerably, but European production had fallen to extremely low levels during the war period because of lack of raw materials. The U.S. increased its production of superphosphate from 4,210,000 tons in 1939 to 9,320,000 tons in 1948, while in France, consumption in the five-year period 1940-45 only equalled the 1938 consumption figure. Nevertheless, production of phosphatic fertilisers in European countries had been increased considerably in the post-war period.

Potash fertilisers

A report on the state of the potash fertiliser market indicated that production in many countries has increased or is scheduled to be raised by the introduction of new plant and the modernisation of existing facilities.

Germany, in pre-war years the leading producer of potash fertiliser (average 1,500,000 tons K_2O) turned out about 1,000,000 tons in 1947-48, or 25% more than in the previous year, and output is now approaching the pre-war rate. Sixty % of production is located in the Soviet occupation zone.

Production in the **U.S.** exceeded 1,000,000 tons in 1948-49 against 970,000 tons in the previous year. The exploitation of new deposits in the Carlsbad, New Mexico, area has been tripled over the past eight or nine years. Production in **Spain** in 1947 reached 150,000 tons or 16% more than in the previous year.

The **French** mines at Alsace are scheduled to turn out 1,200,000 tons of K_2O in 1952, compared with an estimated 850,000 to 900,000 tons in 1949, as the result of modernisation and re-equipment plans.

Among the consuming countries, **Great Britain** used 190,000 tons of K_2O in 1947-48, 55% more than in the previous year and comparing with only 76,000 tons in 1938-39. Potash sales in **Holland** reached 120,000 tons in 1947-48 against 115,000 tons in 1938-39. Against a consumption in **Belgium** in 1938-39 of about 130,000 tons of K_2O, only 120,000 tons were used in 1947-48, but the figure is scheduled to be increased to 140,000 tons in the next year.

Switzerland has almost doubled her consumption of potash fertilisers—20,000 tons K_2O annually against 11,000 tons in pre-war years. **Swedish** consumption in 1948-49 is placed at 38,000 tons against about 30,000 tons annually before the war. In **Norway** more than twice as much was consumed in 1947-48 than ten years earlier—100,000 tons against 47,800 tons. **Finland** used 16,500 tons of K_2O in 1938 and about 30,000 tons in 1947. **Greece** used 4,500 tons of K_2O in 1948 against 3,500 tons in the previous year.

It was pointed out that there are still insufficient potash fertilisers available to meet requirements, despite the overall increase of production from 2,600,000 tons.

British Guiana Air Survey

ARRANGEMENTS are being made for the aerial photographing of 4,000 square miles in the Bartica and Potaro areas of British Guiana. It will be carried out this autumn, and it is hoped that contour maps, which the Directorate of Colonial Surveys will prepare on the basis of the photographs, will be ready about June 1950.

This represents a practical effort to put into operation recommendations made in the report of the British Guiana and British Honduras Settlement Commission (Command Paper 7533). The Commission's aim was to explore openings for the transfer to these two territories of surplus population from the British Caribbean Colonies.

Agricultural developments

Large-scale timber extraction from the Bartica triangle was one of the Commission's proposals. Others included the construction of an all-weather road from Bartica to Potaro and the production of cocoa and other crops in the Potaro and Mazaruni areas.

Development of the interior of British Guiana has been greatly handicapped by the lack of topographic data, and a topographic survey of the areas concerned, in which aerial photography must play an important part, is one of the first essentials for putting the Commission's recommendations into practice.

Colonial Loan

At a recent Press conference in London, Mr. Eugene Black, President of the International Bank for Reconstruction and Development, announced that an application had been made to the Bank by Lord Trefgarne for a loan of $10,000,000 for the purpose of Colonial development.

This loan, which may be the first of a series of similar loans, is to cover a variety of projects in about 20 different Colonial territories.

The right half of this field of corn was sprayed with selective weedkiller

Plant Growth Regulators as Selective Weedkillers

E. HOLMES, M.Sc., F.R.I.C.

Plant Protection Ltd.

A tremendous amount of research and development work has gone into the discovery, production and use of weedkillers in the past half-century. In the earlier stage, botanists and farmers experimented tentatively with standard available chemicals, but nowadays large programmes of work are in progress at research institutions and in the laboratories of chemical firms with the object of discovering new and better chemical compounds with a wide range of specific effects. Progress has been particularly rapid during the past decade, during which British workers discovered the so-called hormone or plant growth regulator types of weedkiller.

The position is reviewed in the following authoritative article.

ANY plant growing in the wrong place is a weed. Consequently any plant, be it crop plant or useless plant, growing on paths, roads or railway tracks is a weed. The most serious weed of railway tracks in Australia is wheat! We therefore need chemicals that will kill all forms of plant life, in other words general weedkillers.

Similarly, almost any plant other than the crop plant growing in that crop is a weed. There are exceptions, of course, such as necessary shade trees in some tropical crops, or green cover crops to stop soil erosion. Weeds in growing crops compete for soil moisture, plant food and light, thereby reducing yields quite markedly in many cases. Until comparatively recently, these weeds have been dealt with solely by hand pulling or mechanical hoeing, but with the general world increase in labour costs and shortage of labour, a demand has arisen for chemicals that will kill out the weeds without serious damage to the crop. These are known as selective weedkillers.

General and selective weedkillers

The general weedkillers cover a very wide range of chemicals, those usually used being based on sodium arsenite, coal-tar emulsions and sodium chlorate. All have disadvantages. The arsenicals are extremely poisonous; the coal-tar emulsions are caustic and not very efficient; whilst the chlorates are very efficient, but under some conditions involve fire hazards. Still other products which have been used for the same purpose are borax, common salt and, not so well-known, the sodium and ammonium salts of the thiocyanates and the sulphamates. The sulphamates have been developed in the U.S. in the last decade

chiefly because they are specially effective against poison ivy.

The main interest of the agriculturist is in selective weedkillers which, at an economic cost, will kill out damaging weeds without appreciable harm to crop plants. Early in the century it was found that if cereal crops were dusted with the fertilisers kainit or calcium cyanamide, or if they were sprayed with dilute solutions of copper sulphate, many of the broad-leaved weeds were killed without any very serious effects on the cereals. In 1911, Rabaté in France demonstrated that dilute solutions of sulphuric acid would similarly kill out broad-leaved weeds such as the charlocks without appreciable damage to the crop. In 1933, again in France, it was discovered that the chemical dinitro-ortho-cresol (D.N.C.) was equally effective against a rather wider range of weeds and did comparatively little crop damage. It was introduced to England shortly afterwards and to the U.S. about 1937.

In quite recent years, a number of derivatives of D.N.C., the sodium and ammonium salts and a number of compounds such as dinitro-secondary butylphenol have emerged as very effective weedkillers in a number of special directions. Unfortunately they are nearly all rather poisonous and require careful handling.

Many of the above chemicals act selectively because of physical differences between weeds and crop plants. Sulphuric acid sprays, for example, are retained on the broad and sometimes hairy leaves of a number of weeds in cereals and kill the weeds by direct corrosive action. On the other hand, the same spray runs down the vertical, smooth leaves of the cereals, doing no damage except possibly to the unimportant outer leaves.

Plant growth regulators

To understand the development of the so-called hormone weedkillers we must go back to an original observation made by Darwin about 1880. He grew seeds of the grass, *Phalaris canariensis*, in the dark and found, as expected, that they sent up a vertical first shoot. When, however, light was introduced from one side only, the shoot bent towards the light. He demonstrated the same effect with oat coleoptiles (first shoots). If the tip of the shoot in either case was removed before exposure to light, no bending occurred.

A series of similar observations was made by a number of research workers in the next 50 years. They eventually led to the belief that something is produced in the growing tip of the plant which, under some conditions, could influence the rate of cell growth in that plant. Thus, if this ' something ' were caused by light to travel down the side of the coleoptile away from the light, and caused elongation of the cells on that side, obviously the coleoptile had to bend towards the light.

Around 1930 the organic chemists decided to take a hand in the work and, when it was discovered that these ' somethings ' also occurred in urine, they attempted to isolate them in order to determine their constitution. In 1933 two chemicals, plant growth regulators, were discovered and called auxin-a and auxin-b, but there is now some doubt whether the constitutions assigned to them are correct. Whatever the truth, in 1934 a further growth regulator was discovered, called hetero-auxin and identified as beta-indolyl acetic acid. This is capable of easy synthesis in the laboratory.

Although these chemicals were all produced from urine they have since been isolated from plants. Their extreme activity is illustrated by the fact that 1 mg. (one 28,000th of an ounce) of auxin-a is enough to cause a bending of 10° in 50,000,000 oat coleoptiles!

Plant growth regulators have found practical application in quite a number of ways; in promoting the more rapid rooting of cuttings, for example of cacao, rubber and tea; for prevention of pre-harvest drop in fruits such as apples and pears, particularly in Australia and North America; for the parthenocarpic production of fruit (that is, causing fructification without fertilisation), especially of tomatoes under glass, and in the prevention of sprouting of potatoes.

Discovery of 'hormone' weedkillers

In 1940, Dr. Templeman was carrying out a piece of work at the Jealott's Hill Agricultural Research Station of Imperial Chemical Industries in Berkshire, in an endeavour to discover whether the application of these products to seeds, cuttings or plants could produce an increase in total yield in the subsequent crop. His observations in this direction were substantially negative. In 1940, however, in the course of an experiment in which he sprayed soil containing oat and yellow charlock seeds, he noticed that alpha-naphthyl acetic acid, applied at rates around 10 to 25 lb. per acre, entirely suppressed the emergence of the weeds without effect on the oats. This was followed by similar observations when growing plants of the same mixture were sprayed. This, it is believed, was the first observation of the selective effect of this type of chemical on different plant species.

Alpha-naphthyl acetic acid at the above dosages was quite uneconomic from the farmer's point of view. In consequence a very considerable programme of experimental work was arranged with Dr. Sexton of the I.C.I. Dyestuffs Division Laboratories in Manchester. Following the examination of large numbers of synthetic chemicals, two particularly active compounds were discovered in 1941 and 1942, namely 2-methyl-4-chlorophenoxyacetic acid and the corresponding 2:4-dichlorophenoxyacetic acid. The sodium salt of the first of these has been named ' Methoxone,' whilst the second has become generally known as 2, 4-D. Prof. Blackman of Oxford has named them M.C.P.A. and D.C.P.A. respectively.

It is interesting to note that towards the end of 1942, Nutman, Thornton and Quastel had also reached the conclusion at Rothamsted that D.C.P.A. was selectively toxic to plants. The first American claim that this compound was a promising herbicide appeared in 1944.

These initial discoveries by Dr. Templeman and the Rothamsted workers were communicated to the Agricultural Research Council in 1943 and, as a result, intensive comparative field trials of the relative

(Photo: Tasmanian Journal of Agriculture

Wild radish in wheat controlled with 0.1% M.C.P.A. in Tasmania

merits of these compounds as against D.N.C. sulphuric acid, etc., were carried out by Prof. Blackman and a team of research workers during 1943-45. Large scale field operations began in 1945 and commercial development was initiated in the following year. Today many hundreds of thousands of acres are treated annually in Britain alone, whilst in the U.S. and Canada the corresponding area runs into millions of acres.

Mode of action

These chemicals cause twisting and discoloration of the stems and leaves of weeds, they cause a thickening and weakening of the stems particularly at ground level, and they may cause the production of rootlets on aerial portions of the plants. Why this happens and the exact mechanism within the plant are not known, but the ultimate result is the death of the weed.

Time of application in relation to plant growth is not very important when dealing with such a susceptible weed as yellow charlock, which may be killed any time from its initial emergence right up to the flowering stage. On the other hand it is obviously best to kill the weed as early as possible to avoid reduction of crop due to competition of the weed for plant food and so on. Probably the best time to control sensitive weeds is when cereals are about 4 to 6 in. high and the weeds big enough to make sure the dust or spray hits them.

With other weeds, timing may be very important. For example, with ragwort and docks, the early seedling stage is very susceptible. On the other hand, excellent results have been obtained with ragwort, docks, thistles and some other perennials by application just before flowering. Doubtless these matters will be better understood when we know more about the inter-relationships of stage of growth, weather and timing of applications.

The action of these new types of weedkiller is comparatively slow. Results may be seen on sensitive weeds within 12 hours in really hot, dry weather, but it may be a week or several weeks before positive results show on the more resistant weeds. Weather conditions definitely affect speed of results, but not the ultimate result very much, provided rain does not occur within a few hours of the actual application. In general it may be said that best results on weeds and least adverse effects on crops are observed when both weeds and crops are growing vigorously.

Although there is some evidence that these plant growth regulators influence the potash metabolism of plants there is as yet little correlation between results and soil types.

Commercial products

The number of commercial weedkillers based on these growth regulators is increasing extremely rapidly, particularly in America, and this can be quite confusing. M.C.P.A. and D.C.P.A. are normally available as the water-soluble sodium salts or actual solutions and these are the two which have been mainly used so far in England. In the case of D.C.P.A., *i.e.* 2, 4-D, the solubility of the sodium salt is rather low, so that means are sometimes sought to increase this property. One easy way is to convert it to what the chemist calls an amine salt and perhaps the most popular is the di- or tri-ethanolamine salt. In addition, and again in America, a great deal of experimental work and publication has taken place on the esters of 2, 4-D, that is, combinations of the 2, 4-D acid with various alcohols. It may therefore be useful to review the comparative efficiencies of these different types of product.

In general the sodium salts are cheapest as weedkillers and least damaging to the crop. It was earlier claimed that whilst the esters were more expensive per pound of active material they were very much more efficient, but that view has had to be modified. The accepted view in America now seems to be that, against really susceptible weeds, the sodium salts, amine salts and esters are very similar in action at equal rates of application in terms of acid equivalent. On the other hand, under difficult conditions such as low-volume spraying in areas with very low atmospheric humidity, the esters in oil solution give much better results than the sodium salts in water. Similarly the ester in oil preparations show greater adhesion to weed foliage and, therefore, better results under heavy rainfall conditions.

It has to be admitted that where slight damage is done to crop plants by these selective weedkillers, the sodium salts are much safer than the esters, whilst the amine salts appear to be intermediate in effect.

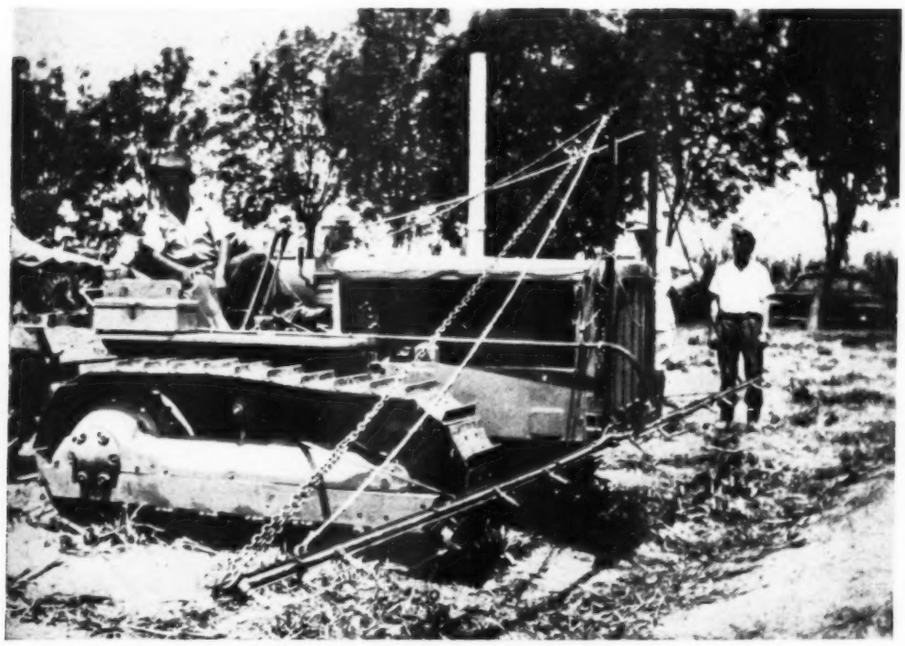
Quite recently, the esters of 2, 4-D and of a new compound 2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid) have given excellent results in clearing up many species of scrub bush, brambles and similar ' weeds.'

Arising from the mention of low-volume spraying, it should be pointed out that conventional sprayers use around 100 gal. of diluted spray per acre. The new low-volume techniques use amounts varying from about 5 to 25 gal. per acre. The quantities of actual weedkiller per acre are substantially the same in both cases.

Results on particular weeds

It is quite impossible in an article of this kind to give any real picture of the tremendous possibilities of these new weedkillers in world-wide agriculture. A few indications, chosen largely at random, must suffice.

Dr. Templeman and others have shown that as little as 2 to 4 oz. of M.C.P.A. or 2, 4-D per acre, suitably diluted, can under research conditions give complete control of such a susceptible species of weed as yellow charlock (*Sinapis arvensis*). On the



Experimental low volume sprayer applying weedkiller to weeds in ratoon cane in Peru

Spraying seedling weeds in rice in Northern Italy

other hand it must be assumed that the average appliance on the average farm is not a very efficient machine. In consequence the amounts of active material normally recommended vary from ½ to about 2 lb. per acre, depending upon the type of machine and the weed concerned.

In Australia excellent results have been obtained against Noogoora burr (*Xanthium pungens*) and Bathurst burr (*X. spinosum*) in pasture with 1 lb. of M.C.P.A. or less. On white turnip (*Brassica campestris*) in cereals in Palestine complete weed control has followed similar applications.

A considerable amount of work has been done in many areas on weeds of sugar cane. For example M.C.P.A. and 2, 4-D, at dosages of ½ to 2½ lb. per acre have given substantially complete control of Spanish needle or black jack (*Bidens pilosa*) in the West Indies and East Africa; of watergrass or listening Willie (*Commelina longicaulis*) in East Africa; of Herbe Bol (*Hydrocotyl bonariensis*) in Mauritius; of the castor bean plant (*Ricinus communis*) and a number of other prevalent weeds in Peru; and of witchweed (*Striga spp*), the parasitic weed, in India.

In America great progress has been made in clearing up that pernicious weed, bindweed or morning glory (*Convolvulus spp*), with 2, 4-D at about 2 lb. per acre in a wide variety of crops.

Finally in this brief summary must be mentioned water hyacinth (*Eichornia crassipes*). This scourge of waterways and irrigation tanks has been cleared very efficiently in India, Australia and elsewhere with one, occasionally two, applications to the foliage of either M.C.P.A. or 2, 4-D at 1 lb. per acre or less.

The effect of these selective weedkillers on undersown crops, particularly clover, is frequently questioned. The position is more complicated than originally thought. First experience was that young clover was usually killed out. It has since been found that undersown crops treated with 'hormone' weedkillers in the very early stages, *i.e.* when the crop, weeds and clover are all small, will result in the destruction of the clover. If, however, application is delayed until there is a reasonable canopy of crop plants and weeds over the still small clover, then complete control of the weeds may be obtained without serious effect on the clover. The crop and weeds shelter the clover from the spray.

Hazards

One or two specific hazards must be mentioned. On cereal crops there has seldom been any appreciable trouble except, perhaps, where applications have been made in the very early stages of growth, and particularly on oats which may be damaged to a small extent in the seedling stage. Similarly, some varieties of barley and particularly the Scandinavian varieties such as Abed Kenia may occasionally have a small percentage of malformed ears as a result of treatment. Occasionally the flowering stem fails to emerge properly from the sheath. In general these malformations do not affect yield or the viability of the resulting grain.

Quite obviously it is necessary to take precautions to prevent these extremely active chemicals from finding their way on to susceptible crops and particularly on to such farm crops as sugar beet, beans and any of the *Brassicas*.

Financial considerations

'Hormone' selective weedkillers are available as dusts and as sprays. Where a sprayer is available there is no doubt that the spray is more efficient and usually cheaper than a dust.

The obvious questions of any farmer new to this type of product are—how much do such applications cost and what are the benefits? Typical costs in Britain have varied, depending upon whether the farmer applies the product himself or utilises the services of a contractor, and upon the susceptibility of the main weeds, anything from 25s. to about 65s. per acre. More recently, however, it has been demonstrated that a large farmer doing his own work with a low-volume sprayer can control the same weeds for from 15s. per acre or less to about 35s.

Under experimental conditions increases of crop yield as the result of such applications have varied from nothing, in the presence of very few weeds, to 150% increase in heavy infestations. With an average to bad infestation of weeds such that some form of weedkilling is called for, the average increase in cereal yield as a result of weedkilling is probably 20 to 25%. At today's prices in England this means an increased return for wheat, on land capable of an average yield, of £4 to £5 per acre.

There are other benefits. A clean crop involves less handling and easier drying in the stook, whilst fewer weed seeds are left to give trouble in the follow crop. Removal of weeds often removes alternative hosts for other pests.

Finally, there is now no doubt that these new weedkillers have come to stay.

Wild radish on plot of wheat controlled with M.C.P.A. in South Africa

UNITED NATIONS SCIENTIFIC CONFERENCE ON THE CONSERVATION AND UTILISATION OF RESOURCES

AT Lake Success, on August 17, the United Nations' Scientific Conference on the conservation and utilisation of resources opened a three-week session. The conference meetings ended on September 6.

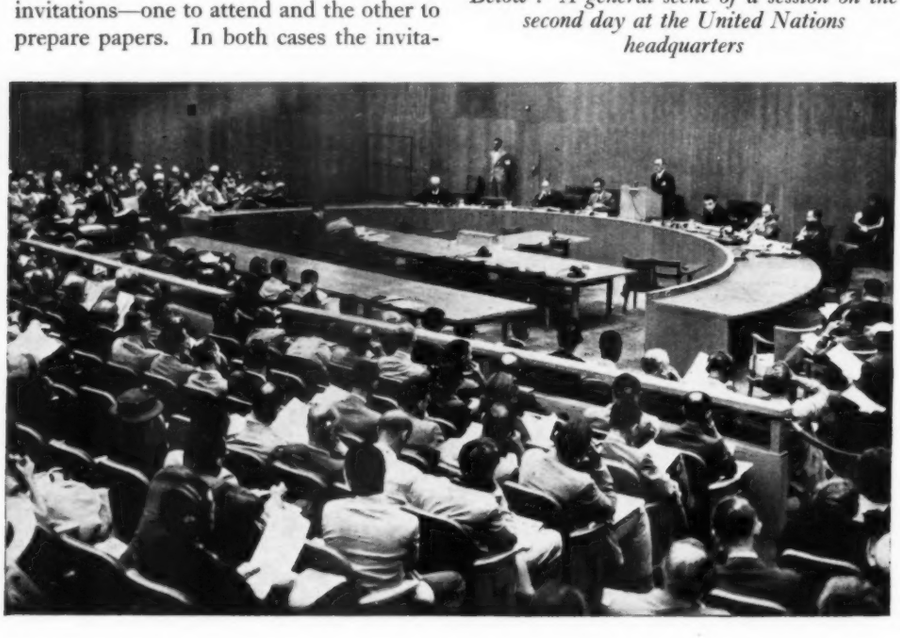
The ultimate aim of this conference is the material enrichment of human life.

The conference was proposed by President Truman in a letter to the United States' delegate to the Economic and Social Council on September 4, 1946 (document E/139). In making the proposal, President Truman emphasised the relation of the conference to the problems of under-developed areas, stating: ' It is my hope that such a scientific conference would bring together all the new techniques of resource conservation and utilisation, particularly for the benefit of under-developed areas, since the problems of these areas represent the hopes of millions of people for freedom from starvation and for opportunity in life.' President Truman proposed that the experts called together ' would not necessarily represent the views of the governments of their nations, but would be selected to cover topics within their competence on the basis of their individual experience and studies.'

The Secretary-General invited experts from 78 countries—the 59 member states of the United Nations, plus the 19 member nations of its missions—to participate in the conference. There were two forms of invitations—one to attend and the other to prepare papers. In both cases the invitations were sent directly to individual scientists as well as to governments and learned societies requesting them to select personnel.

Above : President Harry S. Truman, who proposed the Conference

Below : A general scene of a session on the second day at the United Nations headquarters



Some 470 papers from 45 countries and territories were submitted. The provisional list of scientists and experts who accepted invitations to attend the conference included a total of some 700 experts from 50 countries and territories. In planning the programme and meetings of the conference and in choosing the authors, the Secretary-General had the advice of a Preparatory Committee consisting of individual experts from nine nations and of experts from certain of the United Nations' specialised agencies—the F.A.O., within whose field of action lies so much of the subject matter of the conference, U.N.E.S.C.O., I.L.O. and W.H.O.

The conference devoted approximately half of its programme to the ' interrelation ' of resource techniques, through plenary meetings on subjects of general interest to scientists, technicians, economists and resource administrators. Eighteen such plenary meetings were held.

Fifty-four section meetings were held where experts exchanged views on the detailed aspects of the subjects considered.

Soil conservation

Of particular interest to readers of this journal is the work of the section dealing with land resources, since this includes many aspects of the urgent world problem of soil conservation.

In the session of this section held on August 23 the importance of fundamental soil studies in relation to soil conservation and soil use for production was stressed. Prof. Charles E. Kellogg, Chief of the Division of Soil Survey, U.S. Department of Agriculture, stated that soil classification and mapping were vital in developing efficient soil use and conservation.

The Soil Survey carried on research to determine the characteristics of soils, to classify them, to plot their boundaries on maps and to predict their adaptability to plants, their behaviour under different management practices and the yields of crops.

On the basis of soil classifications the results of experience and of scientific research might be synthesised into alternative recommendations. Knowledge gained through experience or research in one place was relevant to all like places.

Sir William Ogg, Director of Rothamsted Experimental Station, commented on the need to study the possible effect of mechanisation on soil fertility and the problem of soil erosion.

In this connection, problems of mechanisation faced in tropical areas and in Canada were presented to the experts.

At another session discussions dealt with measures concerned with the establishment and execution of conservation policies by governments. Two speakers recommended a decentralised system to promote programmes suitable to local conditions.

At a plenary session over the weekend, the scientists were addressed by U.S. Agriculture Secretary Charles Brannan, who said he thought the strongest expression of the need for using resources efficiently was President Truman's Point Four proposal for technical aid to under-developed areas.

The current conference, Mr. Brannan said, would at least lay the foundation for the programme. Carrying out the programme, he added, ' will be a long and arduous task which certainly cannot get under way until we understand the potential resources in all parts of the world.'

Another weekend speaker, Mr. Hugh H. Bennett, chief of the U.S. Conservation Service, declared that because of lack of conservation there are left only about 4,000,000,000 acres of immediately arable land in the world. This is not nearly enough to produce food for a growing world population, he said, unless modern conservation methods are applied more widely. This step he described as the great need and main hope of civilisation.

Mr. Bennett said that too much of the knowledge gained through research is not being adequately spread and put to use. He told his audience they must be not only scientists but advocates and teachers as well.

Several other speakers mentioned soil utilisation methods. Mr. U. Aung Mying, a Burmese agricultural officer, said farmers in his country would find useful U.S. techniques of terracing, contouring and strip-cropping.

Dr. J. N. Mukherjee, head of the Indian Agricultural Institute at New Delhi, said India's farmers are using improved methods with promise of excellent results.

The question of how to aid farmers in producing more food, better crops and higher yields per acre by means of improved simple tools and equipment for small-scale farming and by mechanisation of farming, was discussed on August 24.

This question was of particular importance to the under-developed countries, declared Prof. Frederick Hardy, Imperial College of Tropical Agriculture, Trinidad, British West Indies, who presided as chairman. Few investigations, he said, had hitherto been made of the needs and problems of the small grower, and the implements which would economically and effectively serve his requirements.

J. N. Mukherjee of India introduced a paper on simple tools and equipment for small-scale farming, prepared by Mason Vaugh, agricultural engineer, Allahabad Agricultural Institute, India.

We hope to publish a more complete account of the proceedings of this important conference in our next issue.

Mr. Raymond E. Marsh (left) of the Forest Service, U.S. Department of Agriculture, discusses forestry problems with Lord Robinson, chairman of the Forestry Commission, United Kingdom

M. Egbert de Vries of the Netherlands Ministry of Overseas Territories, chatting with Sir Hubert Broadley, Deputy Director-General of the F.A.O. (right)

Below: Left to right. Mr. F. N. Woodward, Director of Scottish Seaweed Research Association, Sir William Ogg of the Rothamsted Experimental Station, Mr. M. Graham, Director of the Fishery Research, U.K., Mr. F. Harvey, of the Imperial College of Tropical Agriculture, Trinidad, and Mr. A. King, Chief Scientific Adviser, Office of the Lord President of the Council

A typical village scene in Pakistan—bullocks drawing a water wheel

Agricultural Progress in Pakistan

The second anniversary of Pakistan's independence was on August 14. This article on food problems and plant protection in Pakistan is intended as a résumé of the progress of the country in the past year.

IN 1948, the various surplus units of Pakistan declared a surplus of 333,000 tons of food grains, which was more than adequate to meet the requirements of the deficit units. But, unfortunately, both in West Punjab and East Bengal there were very heavy rains accompanied by unprecedented floods. The Begari Bund of the Indus also gave way. The food position accordingly received a very serious setback. The crops in two surplus districts of East Bengal were completely washed away. In Sind, the rice crop was very severely damaged and in the West Punjab crops in a number of districts were seriously affected.

The set back gave an impetus to unsocial elements which started their malpractices. Smuggling, hoarding of food grains and black-marketing became very prevalent. Unfortunately, the prices of food grains in the neighbouring country were four times the prices in West Pakistan, which provided a great incentive to smugglers.

The long Indo-Pakistan border could not be sealed off, but all possible steps were taken to check this unsocial activity. The strength of the enforcement police was considerably increased. They were also provided with arms and ammunition and the means of quick transport. The penalty for these offences was enhanced and, in certain cases, exemplary punishments were awarded. A ban was also imposed on private carrying of food grains within a certain area of the border. All these steps had a very salutary effect and smuggling was very considerably reduced.

Measures against hoarding

Internally, the evils of hoarding stocks of food grains and black-marketing became a serious menace. The various units took anti-hoarding and anti-black-marketing legislative measures and penalties for not declaring stocks or hoarding quantities of food grains in excess of certain quantities were adopted. The scale of food ration was reduced. A ban on the manufacture of certain wheat products was imposed and the number of guests at entertainment parties was restricted. Serious wheat shortage occurred in the North-West Frontier Province, Baluchistan and West Punjab. In the West Punjab, even the breakdown of the rationing system was apprehended at one stage.

To meet the situation the Food Ministry embarked on a programme of imports from foreign countries. An application for the allotment of 160,000 tons was made to the International Emergency Food Council. Other sources were also tapped. Wheat was purchased from Russia and some quantities of coarse grains, maize and barley were procured from Hungary, Yugoslavia and Australia.

The imported food grains very much reduced the profits of black-marketing and the hoarders had to disgorge their stocks. The result was that at a time when scarcity was expected to be the acutest, prices began to show a downward trend. This also taught the hoarders a good lesson, with the result that this year the procurement of food grains by the various units are much better than expected. Food ration has been raised to 8 chattacks per adult per day throughout Western Pakistan and the compulsory ration of rice has been withdrawn. It is confidently hoped that Pakistan will not have to import any wheat during the crop year.

In Eastern Pakistan

The food position in Eastern Pakistan was unsatisfactory. The rice deficit of that province was previously accepted by the centre to be 140,000 tons, out of which 68,000 tons were to be met from Sind and Baluchistan. The International Emergency

Food Council allocated 33,000 tons of rice from Burma, Egypt and Italy. There still remained a balance of 49,000 tons to be found for Eastern Pakistan from other courses. The food position in East Bengal, however, further deteriorated, and its deficit in rice was reported to be about 700,000 tons. Vigorous efforts were made to get further quantities of rice from abroad. So far about 45,000 tons more have been secured and application for further assistance through the International Emergency Food Council is under consideration. Sind has in the meantime offered another 20,000 tons of whole rice and about 5,000 tons of Kangni broken.

For the current year, the total quota of food grains for East Bengal is 348,000 tons, consisting of 170,000 tons of rice and 178,000 tons of wheat and wheat products. Of this quantity 93,399 tons of rice and 33,530 tons of wheat have already been despatched. Arrangements have now been made to send 30,000 tons of food grains from West Pakistan and 15,000 tons from other sources every month to East Bengal and thus effectively remove food scarcity there.

Of the total quantity of rice, the despatch of which is to be completed by November 1, 1949, 84,000 tons were procured from Sind, 11,000 tons from Baluchistan, 60,400 tons from Burma, 5,000 tons from Egypt, 8,000 tons from Italy and 1,600 tons from other sources. The despatch of East Bengal wheat quota is to be completed by April 30, 1950, of which 46,000 tons were procured from the West Punjab, 3,000 tons from Khairpur and 62,000 tons is imported wheat lying in Karachi.

Sugar

The sugar requirements of Western Pakistan at the increased ration scale come to 168,000 tons. Eastern Pakistan has been consuming about 25,000 tons a year, which is near about their own local production. In the beginning of the year 1948 Pakistan purchased fairly large quantities of sugar from soft currency areas like Brazil. Later on, when the Brazilian Government placed an embargo on the export of sugar, Pakistan was compelled to go to the hard currency areas. During the first quarter of 1949, Pakistan received 47,000 tons of sugar from overseas. A further 60,000 tons have been purchased through the embassy in Washington. Out of the sugar thus purchased, 67,000 tons have been received. A British Government offer of 55,000 tons of refined sugar has been accepted.

Edible oils

Pakistan is heavily deficient in edible oils and oil seeds. The shortage is more acute in East Bengal, which is predominantly an oil-eating area. To meet this deficit, the Government encouraged import of these commodities from whatever source was available. Import of edible oils and vegetable oil products from soft currency areas was placed on the open general licence.

Under a new agreement arrived at between the Government of the United Kingdom, Ceylon and Pakistan, Ceylon is to supply 6,000 tons in terms of copra oil to Pakistan during 1949. India has also agreed to supply Pakistan under the latest Inter-Dominion Commodity Exchange Agreement during July 1, 1949, to June 30, 1950, with 60,000 tons of mustard oil, 15,000 tons of groundnut oil, 6,000 tons of copra oil and 15,000 tons of vanaspati.

Plant protection

Large breeding areas of desert locust lie in Western Pakistan, as well as in the adjoining countries of Iran and Arabia on the one side and India on the other. Pakistan is therefore vitally affected by the breeding of locusts on its own soil and by immigration from the neighbouring countries. The Plant Protection Department of the Government keeps a vigilant watch over the breeding of locusts. Information received from various locust posts is collated and mapped and periodical bulletins are issued for the information of provinces and states in Pakistan as well as of other countries.

Locust operations in Oman

Pakistan participated in the Anti-Locust Conference held at Teheran in September 1948 at which a recommendation was made that Pakistan should arrange to survey and control locusts in the Oman Peninsula (Arabia), which is an important outbreak centre affecting the territories of Iran, Pakistan and India. An anti-locust delegation from Pakistan was accordingly sent to Oman in January 1949. This delegation organised control measures in co-operation with the local authorities and its work is expected to be of far-reaching importance. It was highly appreciated, among other organisations, by the Anti-Locust Centre, London, and by the Desert Locust Survey, Nairobi. A joint locust survey of Iranian and Pakistanian Mekran (Baluchistan) has been carried out in collaboration with Iranian locust parties. A small locust breeding area between the Pakistan boundary and Qasarqand in Iran was located.

Another recommendation made at the Teheran conference was that a wider conference of technical experts of Iran, Pakistan, India, Egypt, Anglo-Egyptian Sudan and the U.K. should be held as soon as possible to co-ordinate work on an international scale. This conference is being organised by the Government of Pakistan and it is expected to take place this month at Karachi.

Plant Protection Service

A Plant Protection Service was organised in Pakistan immediately after partition. This service was mainly responsible for controlling the black-headed cricket in Kalat, Sind and Baluchistan. These insects damage harvested wheat, sorghum and oilseeds lying on threshing floors to the extent of 10 to 25%. A scheme for the co-ordinated control of these insects,

Contrasting in happy juxtaposition a horse-drawn tonga crosses the modern Sukkur Barrage

Local workers in a Bengal jute factory. Jute is one of Pakistan's main assets

covering an area of 400,000 acres, has been functioning since April 1949. The other activities of the service were the cleaning and spraying of apple trees against codling moth, hairy caterpillar, black and green aphids. Several thousand almond trees, heavily infested with almond scale, were also sprayed and the pest brought under control.

Many of the finest fruits of Pakistan suffer heavily from ravages of insect pests and diseases. Some of these, like codling moth, hairy caterpillars, etc., have entered Baluchistan and the North-West Frontier Province with fruits imported from the west. Large-scale spraying operations to kill them before they spread into other parts have been in operation in Baluchistan and a similar scheme for the N.W.F.P. and the tribal areas has been recently sanctioned.

In an improvised laboratory at Karachi, Trichogramma parasite, which feeds on the eggs of sugar cane borers and thus controls its ravages, is being mass multiplied, producing about 30,000 parasites per day. Periodical consignments of these useful tiny insects are being sent to Sakrand and Mirpur Khas for liberation in sugar cane fields to find out their efficacy in controlling the sugar cane borers.

In order to combat the ravages of rust, particularly in Baluchistan, the work of breeding resistant varieties has been taken up. Steps were also taken to control the fusarium wilt disease of potato in the autumn of 1948 in Baluchistan.

Quarantine plants

An organisation for the quarantine of plants and plant products has been set up with a view to prevent the entry of exotic insects and diseases. Plant quarantine outposts have been set up at Karachi, Chittagong, Chaman and Peshawar for this purpose. All imports of plants and plant materials are examined and health certificates are issued in respect of dried fruits and other commodities which are being exported from Karachi. During the last year quantities of dry fruits were, examined and exported under health certificate issued by the Plant Protection Department.

Land reforms

As the second year of independence was completed, the tillers of the soil in East Pakistan, constituting about 95% of the total population, can safely look forward to the amelioration of their condition as a result of the various agrarian reforms and enactments undertaken by the Provincial Government. Some Acts have already been passed by the Provincial Legislative Assembly, while the most important legislation —the State Acquisition Bill, envisaging the abolution of the Zamindery system—is expected to be passed shortly.

To regulate the rights and liabilities of the tenants of the non-agricultural lands *vis-a-vis* their landlords, another important legislative measure—the East Bengal Non-Agricultural Tenancy Bill, 1949—was passed by the Assembly during its last session. The incidence of non-agricultural tenancies had so far been governed by the terms of contracts and the provisions of the Transfer of Property Act, 1882. But as the provisions of that Act did not provide for adequate protection to the lessees, the new Bill has been passed. It seeks to give to the non-agricultural tenants, possessing non-agricultural lands for a period of 12 years or more, permanent heritable and transferable rights in such lands. Provisions have also been made in the Bill for protecting all non-agricultural tenants against illegal exactions and arbitrary eviction and enhancement of rents.

According to the Inter-Dominion Agreement, a Bill for the protection and management of evacuee property in this province has been passed.

Jute

The Government of East Bengal formulated their policy regarding the production and export of jute—the golden fibre—in such a way as to maintain the virtual monopoly of the supply of the commodity throughout the world and to create circumstances under which the growers can receive a fair price for their produce.

About 75% of the entire world production of jute, and indeed all of the best quality of it, is grown in East Bengal. The normal annual consumption of jute overseas is about 3,000,000 pressed bales of 400 lb. each. The output of pressed bales from East Bengal increased from 904,674 during the year 1947-48 to 1,135,823 this year.

In order to enable the growers to sell their crop with full knowledge of the prevailing market rates in Calcutta as well as the baling centres in this province, the Government have made elaborate arrangements for disseminating quotations of prices of different grades of jute. To further safeguard their interests against all sorts of prevalent malpractices a sub-committee has been formed and entrusted with the task of devising ways and means for fixing definite standards of the different grades of jute, weights used by the buyers while purchasing it, etc. For regulating and controlling the jute prices and for standardising the baling capacity of presses, two other sub-committees have been formed, while steps have been taken to acquaint the growers with the art of assortment of jute in different grades.

To minimise the chances of exploitation of the growers by the purchasing parties, the East Bengal Jute Dealers Registration Ordinance, 1948, under which all categories of dealers are to be registered and licensed, has been promulgated, while a monthly bulletin giving a summary of jute statistics comprising all possible data relating to the condition of jute markets both inside this province as well as abroad is regularly published. The utility of this bulletin having been recognised both in the U.K. and the U.S.A., many foreigners have become regular subscribers.

Cultivation of Wet Rice

MECHANICAL METHOD USED IN MALAYA AND SIAM

A NEW method is being used in Malaya and Siam for the cultivation of wet rice. In the past it has been the habit of the rice growers to use water buffaloes or bullocks for this task, but in Siam certain growers are adopting a different method of cultivation.

Using the power take-off pulley of the 'Howard Rotavator Gem' to provide the power, cultivators are pumping the water from one sawah over the bund into the next sawah. The field from which the water has been pumped is allowed to dry out for a short period, and then the 'Rotavator' is put into the field to do the cultivation by means of its revolving blades.

It will naturally take some while for this to become general practice and, as an alternative, the manufacturers of this tractor have recently modified their standard machine by equipping it with extra large wheels. These wheels penetrate the mud and find the bottom. It is obvious that there are two approaches to this problem, either a machine may be made to float on top of the mud, or else special wheels may be provided which will penetrate the silt. Both methods have been tried, and the latter is considered to be the more efficient.

A Siamese farmer cultivating a rice field after the water has been pumped off by the machine

The simplicity of the machine and the fact that all the operations can be done with the one tool make it extremely easy for the Siamese, Malayan or Burman to use, and it is considered that these machines will very greatly assist in the production of more rice at less cost.

The machine pumping off the water from a sawah. The same machine that is used for cultivating is adapted for pumping operation

Tea Production in 1948

Data for the world production of tea in 1948 are now to hand from various sources.

In India and Pakistan production reached an all-time record of 597,000,000 lb. as compared with 587,000,000 lb. in 1947 and an annual pre-war average of 425,000,000 lb.

No figures are available for total production of tea in China, but exports from there, including Taiwan, totalled 38,584,000 lb. as compared with 36,251,000 in 1947 and an annual average of about 104,000,000 in the immediate pre-war period. Taiwan exports accounted for approximately 45% of the 1948 total.

In Indonesia recovery is proceeding moderately rapidly. The Indonesian authorities consider that the total potential production of tea had been reduced by 50% as a result of the war. Actual production in 1948 is stated to be 24,747,000 lb. as compared with just over 3,000,000 lb. in 1947 and a pre-war average of 177,000,000 lb. Current indications point to a 1949 harvest of more than 45,000,000 lb.

In British East Africa production declined about 17% and exports dropped 24%. For the three territories Kenya, Tanganyika and Uganda, production was estimated at 15,500,000 lb. compared with 18,600,000 lb. in 1947 and an average pre-war production of 10,000,000 lb.

Irrigation Developments in Aden

In low-rainfall areas it is common to find that such rain as falls occurs as heavy downfalls within a limited period and agriculture depends on utilising the floods which come down the dry river channels to irrigate the land so that crops can be grown. This system is traditional in many other parts of the dry tropics.

The art of man has for long been directed towards controlling and conserving these floods so as to ensure that the maximum benefit is derived from the water. A recent effort in this direction is in the Protectorate of Aden where a scheme conceived by Mr. B. J. Hartley, Director of Agriculture, has been inaugurated to conserve the water in the Wadi Bana. Dams to arrest the flow of water have been built and below them a series of weirs dropping step by step to the sea. The scheme was originally started in 1940 and has been assisted by grants under the Colonial Development and Welfare Act. It is hoped that by 1951 10,000 tons of food as well as a certain amount of cotton for export will be produced annually. The total area worked under the scheme will then reach 60,000 acres.

WORLD CROP REPORTS

British East African Coffee Exports Higher

British East Africa exported 1,076,782 bags of green coffee in 1948, compared with 695,900 bags in 1947 and the pre-war (1935-39) annual average exports of 732,000 bags. Latest estimates place the 1948-49 production at 1,023,100 bags, which compares with 813,000 bags in 1947-48 and an annual average 1935-39 production of 785,000 bags, according to the American Consulate General in Nairobi.

The United Kingdom, British East Africa's principal export market, took 521,935 bags of coffee in 1948 compared with 238,909 bags in 1947 and an annual average of 131,627 bags in the pre-war period. The United States imported 12,531 bags of coffee from British East Africa in 1948, compared with 85 bags in 1947 and an annual average in 1935-39 of 97,734 bags. The Union of South Africa, British Malaya, Australia and Canada also took considerable quantities of coffee from British East Africa in 1948.

Indian Castor Bean Production Decreases

Indian castor bean production for the 1948-49 season (January-February harvest) amounted to 122,080 short tons from 1,406,000 acres, according to the final estimate. The decrease of 8% from the 132,160 tons (revised) produced in 1947-48 is attributed mainly to smaller production obtained in Hyderabad, the chief producing area.

Philippines May Increase Minor Oilseed Crops

Production of minor oilseed crops in the Philippine Republic, which in the past has been on a relatively small scale, is expected to increase somewhat in the next three years, according to the American Embassy, Manila. These crops are peanuts, soya beans and lumbang nuts.

Peanut production totalled 8,200 short tons in 1948, or about 1,000 tons more than the output in 1939. Although a number of areas are well adapted to growing peanuts, the crop has not attained prominence in the agriculture of the Philippine Republic. There is no commercial crushing of peanuts for oil since the output is consumed largely in roasted or salted form.

Soya bean output in 1948 is estimated at about 18,000 bushels, 65% more than the 10,900 bushels produced in 1939. Soya beans also are not important as a source of oil in the Philippines, since they are consumed as food in other forms.

Lumbang, or candlenut, production at 138 tons last year was less than the 160 tons produced in 1939. The oil obtained from the lumbang nut, which yields at the rate of 17.5%, is closely related to tung oil. In the Philippines it is used in the manufacture of paint and varnish.

The gradual expansion of the Philippine vegetable lard industry has precluded the commercial production of both lard and tallow. A small amount of lard, which is imported, is consumed mainly by the Chinese population. Tallow and grease, used in hardening soaps, are obtained from off-shore sources.

High Grain Yields in U.K.

Exceptionally high yields of grain have been obtained this year in the United Kingdom. According to a recent Ministry of Agriculture estimate, the wheat yield is 21·3 cwt an acre compared with a 10-year average of 18·7 cwt and last year's record figure of 20·7 cwt. For barley the estimated yield is 19·8 cwt against a 10-year average of 17·5 cwt and last year's figure, also the previous highest, of 19·4 cwt. Oats, too, show the same heavy yield with 18·4 cwt compared with 16·6 cwt and 17·7 cwt.

Brazilian Coffee Crop

The 1949-50 Brazilian coffee crop is expected to be small, which is probably an incentive in the drawing up of elaborate marketing plans by the Minister of Finance. The plans cover transport and warehousing, etc., in extraordinary detail and fix stock limits for liberated coffees at the various ports.

Out of a port total of 3,710,000 bags, Santos is allowed a limit of 2,200,000 bags; Rio de Janeiro and Niteroi 700,000; and Paranagua and Agra dos Reis each have 300,000 allotted to them. These amounts, however, may be varied, one way or the other, at the judgment of the ' Divisao da Economia Cafeeria,' provided exportation interests should so demand.

Percentages of qualities of the coffee in stock at the ports can be varied to satisfy the demands of consuming markets, always providing that the coffees are satisfactory as regards being hand-picked, well-dried, of characteristic and uniform colour, type not inferior to No. 3, of characteristic roast and of ' soft to better drink.'

Peru's Rice Production Below Requirements

Peru's 1949 rice acreage is much smaller than in 1948, according to its Ministry of Agriculture. Unless unusually high yields per acre are harvested, the crop is expected to be between 40 and 50 million lb. less than the 245 million lb. distributed for consumption in 1948. Lack of rainfall in northern Peru during January and February, and the uncertainty of Government prices for the crop accounted for the reduction in acreage. Rice growers are protesting against the new base price for this year's crop provided in a decree of May 14, 1949, and have asked the Ministry of Agriculture to fix a new price level in view of high production costs.

Ecuadoran Rice Crop Prospects Favourable

Ecuador's 1949 rice crop may be 20% larger than in the preceding year and nearly 150% greater than pre-war, according to Henry L. Coster, American Vice-Consul, Guayaquil. The harvest is forecast at 8,400,000 bushels (245 million lb. milled), compared with 6,945,000 bushels (203 million lb.) in 1948. Pre-war (1936-40) production averaged approximately 3,400,000 bushels (100 million lb.) annually. Weather conditions this year have been favourable for rice production.

Domestic consumption of milled rice is estimated at around 80 million lb., which will allow more than 150 million lb. for exports abroad. This new crop will begin to be marketed in June. Stocks on hand from the previous year's crop were reported on April 15, 1949, at around 20 million lb.

West Indian Sugar

The West India Committee has published the following figures of estimated production during the quota year ended August 31, 1949 :

	Tons
Barbados	153,000*
Jamaica	233,601
Antigua	16,000
St. Kitts	34,000
Trinidad	159,032
St. Lucia	9,128
St. Vincent	2,084
British Guiana	184,229
British Honduras ..	2,108
	793,182

**Including fancy molasses, 20,000 tons sugar equivalent*

World Wheat Production

In the September issue of WORLD CROPS, U.S. Department of Agriculture estimates of world wheat crop were given as 5,000,980,000,000 bushels in 1948. This should have read 5,000,980,000 bushels.